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Salmonid Spawning Analysis Model
Project Completion and
Model Documentation

S S A M

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PROJECT COMPLETION REPORT AND MODEL DOCUMENTATION

USDA - ARS/FS Cooperative Agreement INT-90480-IA

PREPARED BY

Robert N. Havis

PROJECT LEADERS

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Carlos V. Alonso

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ABSTRACT

A simulation model (Salmonid Spawning Analysis Model, SSAM) was developed to evaluate the relative impacts of land management on salmonid spawning habitat. Software in common use in the U.S.A. were adapted for use in gravel bedded rivers and linked to simulate water temperature (the U.S. Fish and Wildlife Service Instream Water Temperature, SNTEMP model) and water and sediment routing (the U.S. Army Corps of Engineer Scour and Deposition in Rivers and Reservoirs, HEC-6 model, version 3.2). These models drive the redd (spawning nest) model (the U.S.D.A. Agricultural Research Service Sediment Intrusion Dissolved Oxygen , SIDO model) which simulates sediment intrusion and dissolved oxygen concentration in the redd environment.

The HEC-6 model was adapted to gravel bedded rivers through partitioning suspended and bed load based on shear velocity. A quasi 2-dimensional flow and bed load routing scheme was implemented through calculating river hydraulics for user defined stream tubes or subsections. Using the lateral variability in flow and depth, the bed load was distributed in the cross section based on the square of the unit discharge. The intrusion of bed load material into the porous gravel framework of the redd was simulated through examination of the velocity and trajectory of bed load particles. The SIDO model was extended to simulate clogging within the interstices of the porous gravel as well as complete filling of the framework material.

The SSAM model was evaluated with field data from Poverty Reach, an established salmonid spawning ground on the South Fork of the Salmon River in Central Idaho. The HEC-6 model was validated using water profile and sediment load measurements and the SNTEMP model was evaluated using instream water temperature measurements. The sediment intrusion model was calibrated using a field study program which employed intrusion buckets that were installed in the river substrate. The SSAM model predictions of dissolved oxygen and water temperature compared favorably with data from artificial redds containing hatchery chinook salmon eggs.

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INTRODUCTION

BACKGROUND

Fine Sediment in the Spawning Environment

Commercial and sport benefits resulting from anadromous fisheries averaged $434 million (US) annually in the Pacific Northwest in the 1970's. Because of reduced anadromous fish populations, this value represents less than half the potential (Theurer 1985). Reduced spawning success because of watershed development is one of the major contributors to reduced populations of anadromous species. A large body of literature illustrates that fine sediment is detrimental to egg survival and developing embryos (Meehan and Swanston 1977, Cooper 1965, Chapman 1988, Platts et al. 1979, Iwamoto et al. 1978). Major reasons for increases in fine sediment loading to spawning areas are agricultural development (Theurer 1985) and forest harvesting and associated road building (Platts and Megahan 1975).

Salmonid species spawn in the gravels of freshwater streams. The nest, or redd, is a pocket of gravel from which the female has partially removed the sediment fines. Details of the redd construction process can be found elsewhere (Chapman 1988). Large populations of spawners returning annually to a particular location serve to maintain a high quality spawning habitat. A large area of gravel, cleaner than the surrounding stream substrate, develops in these areas (Chapman 1988).

Fine material inevitably moves back into the redd environment after construction. The rate of movement depends on upstream sediment sources and precipitation or snow melt events. The specific impacts on the developing embryos and fry depend on particle size and composition. Clays and silts cause low intragravel hydraulic conductivity, thereby, reducing water flow and oxygen supply, and the removal of metabolic waste products. Larger intruding

particles (0.85 mm to 9.50 mm) may create a seal or clogged layer within the gravel framework preventing fry from emerging from the redd.

Fine sediment occurs in suspension over a wide range of flow rates. Intrusion rates of suspended sediment into porous gravels depend on the sediment concentration near the bed (Alonso and Mendoza 1991) which may be several orders of magnitude higher than in the upper portions of the water column (Alonso et al. 1988). Although not necessarily in constant suspension, fine sands may be transported across the stream substrate at relatively low flow rates. When the flow reaches a critical discharge in gravel bed rivers the movable bed portion of the stream substrate is set into motion carrying many size fractions from fine clays and silts to coarse gravels.

Sediment Intrusion Mechanisms

As sediment material moves across a porous gravel framework, such as the redd environment, some of the material intrudes into the gravel following flow paths caused by intragravel circulation in the porous gravel and through gravitational settling. Small size fractions, such as those found in the suspended load, may intrude to the bottom of a gravel deposit filling pores from the bottom towards the surface (the Einstein intrusion mode, Einstein 1968, Fig. I-1). Also, when cohesive particles intrude a gravel framework, flocculation may occur reducing intragravel flow velocities (Kovacs 1981). However, in the presence of larger bed load material the intruding particles may bridge the gravel framework voids creating a seal that traps further intruding fines at some distance between the gravel surface and the undisturbed underlaying material (the Beschta intrusion mode, Fig. I-2).

Laboratory column studies (Sakthivadivel and Einstein 1970) show that intruding particles with a mean diameter greater than one 14th of the mean diameter of the gravel framework created a sealed layer midway in the column;

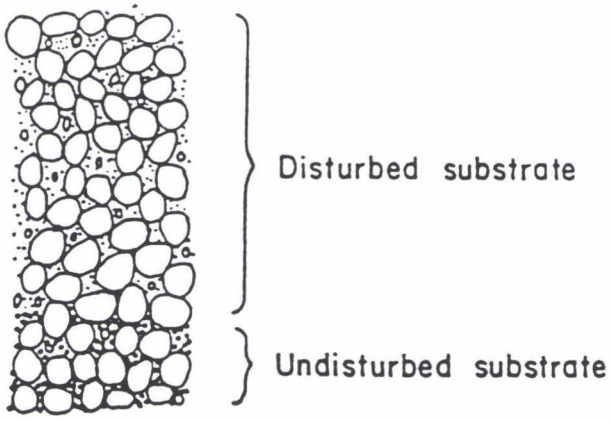


Fig. I-1. Filling of the Porous Gravel Deposit by the Einstein Intrusion Mode (from Alonso et al. 1988)

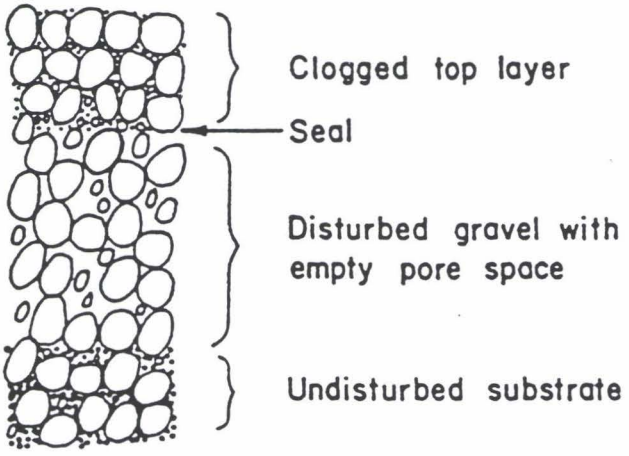


Fig. I-2. Sealing in the Upper Layers of the Porous Gravel Deposit by the Beschta Intrusion Mode (from Alonso et al. 1988)

while smaller particles filled the gravel framework from the bottom to the surface (the Sakthivadivel criterium). Flume studies (Beschta and Jackson 1979), with a Froude number of less than 0.9, showed that 0.2 mm Dia. sand filled the voids in a 15 mm Dia. gravel framework from the bottom to the surface; but a 0.5 mm Dia. sand created a seal about 5 cm from the gravel surface. Here the Froude number is defined as the square of the mean water velocity divided by the acceleration due to gravity and flow depth. At Froude numbers greater than 0.9 the 0.5 mm sand intruded to about 10 cm. This deeper intrusion was attributed to gravel movement under higher flow rates. Similar results have been obtained in other laboratory (Carling 1984, Diplas and Parker 1985) and field studies (Lisle 1989, Frostick et al. 1984). Models of the sediment intrusion phenomena come from engineering practice and recently from theoretical studies.

Geotechnical filter design criteria rely on statistical properties of the sediment size distribution (Cedergren 1977). These criteria are in general agreement with findings from flume studies (Diplas and Parker 1985) which showed that a seal will develop when $5D_{15}$ (sediment) < D_{15} (gravel framework) < $5D_{85}$ (sediment) (the Diplas and Parker criterium). The depth of the sediment seal occurred between 2.5 to 5 X D_{90} (gravel framework) showing close agreement with the seal depths measured by others (Beschta and Jackson 1979).

Theoretical models of the intrusion process have utilized probabilistic and statistical methods. Although the packing of non-uniform spheres poses a significant analytical problem (Visscher and Bolsterli 1972) the resultant void size distribution is even more complex. A stochastic analysis of grain cord and void cord distribution has been used to estimate soil particle penetration of a geotechnical filter (Aberg 1978). Through transforming particle size distribution by weight to a discrete distribution by diameter, a void size distribution can be derived which is amenable to probabilistic analysis. Assuming three spheres in contact, a multinomial method has been

suggested to find pore size distribution (Silvera 1965). This approach has been extended (Lauck 1991) through applying a dimensional bias to the probability distribution functions to generate a family of pore size distributions.

The sediment intrusion models employed in this study were developed to serve as management tools to analyze the relative effects of increased sedimentation from land management practices on salmonid spawning habitat. The models employ engineering approximations to provide reasonable predictions in an efficient computational environment. The purpose of this paper is to describe a model of salmonid spawning habitat and to compare simulations of redd water chemistry with redd habitat data from a field study site.

SALMONID SPAWNING HABITAT MODEL (SSAM)

Overall Model Design

The spawning habitat model is an ensemble of software packages linked to simulate water quality in the redd environment. The United States Army Corps of Engineers, Hydraulic Engineering Center's, Scour and Deposition in Rivers and Reservoirs model (HEC-6, Version 3.2, Hydraulic Engineering Center 1977) is used to route sediment through a stream reach with spawning grounds. The U. S. Fish and Wildlife Service's Instream Water Temperature model (SNTEMP, Theurer et al. 1984) estimates water temperature, a variable used in HEC-6 calculations, and an important factor in salmonid spawning success. The SNTEMP model uses river width, estimated in HEC-6, for heat transport calculations. These two linked models exchange information on a daily time step. Output from these simulations are used to drive the US Department of Agriculture's Sediment Intrusion Dissolved Oxygen model (SIDO, Alonso et al. 1988) in simulations of the redd environment. Because HEC-6 was originally developed to model sand bedded rivers, several modifications are needed when

applying the model to gravel bedded rivers.

Water Temperature

The SNTEMP model uses solar and meteorological data to drive the heat transport calculations for a river reach. The reader is referred to the SNTEMP documentation (Theurer et al. 1984) for details of the mathematical methods. The heat transport module has been linked to run interactively, on a daily time step, with the river hydraulics model (HEC-6) in simulations of water temperature and sediment transport. Thus, the calculation of heat transport through the water surface employs river width estimates from HEC-6. However, heating of water through solar radiation is based on channel widths defined by the user in the optional solar shade data file and the river widths used for solar shade calculations are not up dated daily. This is not considered a significant limitation in water temperature calculations because air temperature and water source temperature are the major factor driving heat transport in river systems.

River Mechanics

The HEC-6 model uses a one-dimensional flow, total-sediment load, computational scheme. To separate the suspended and bed load material for sediment intrusion calculations, the size fraction settling velocities are compared with the turbulent shear velocity. The HEC-6 model was adapted for use in gravel bedded rivers with large lateral variability in flow and sediment transport. Hence, cross sections were divided into subsections where geometry and hydraulic variables are calculated for each time step in the vicinity of spawning locations of interest. Suspended sediment load is in direct proportion to the flow rate. Many empirical relations show that sediment transport is a power function of stream flow with an exponent of about 2.0 (Knighton 1989). Therefore, bed load is weighted, laterally in the

cross section, in proportion to the square of the subsection unit discharge. Using these approximations the one-dimensional HEC-6 model was modified to simulate quasi two-dimensional flow and bed load sediment transport.

Through emulating lateral variability with a one-dimensional model more precise estimates of sediment load and hydraulic geometry in the vicinity of the redd are achieved without excessive expense. The estimates of local water depths at individual redd sites allows more accurate calculation of the hydraulic pressure gradients that drive intragravel flow. The concentration of suspended load at the stream/gravel substrate interface is calculated based on the average suspended load concentration and the velocity profile (Alonso and Mendoza 1991). The bed load sediment concentration is calculated on the basis of an average bed load particle velocity and expected range of motion with respect to the bed. Details of these modifications to HEC-6 are discussed below.

Water Flow. Details of the methods used to simulate water and sediment flow in the HEC-6 model can be found through the HEC-6 users manual (HEC, 1977). The HEC-6 model uses the standard step method for calculation of surface water elevations. Sediment transport is simulated through calculation of the total sediment load using one of 5 different transport capacity functions: the Toffaleti method, a user defined method, the Madden-Laursen method, the Yang method and the Duboys method. The Exner equation is employed to simulate continuity of bed material transport. The bed stability factor, introduced by Gessler (1970), is used to evaluate the stability of bed particles. Modifications to the HEC-6 water and sediment flow calculations take the form of subprograms which extend the HEC-6 calculations to provide more geometric and hydraulic detail for use in sediment intrusion calculations. The function of these subprograms is discussed below.

Because HEC-6 simulates one dimensional flow each cross section is

characterized be a single, mean: water velocity, flow rate, depth and energy slope. In gravel bedded rivers lateral variability in these variables is often significant. Therefore, details of the hydraulic geometry and flow characteristics across the river width are calculated in the subprogram HYPROP. At each daily time step the cross section geometry, depth and energy slope, is read by HYPROP for user selected cross sections.

For each user selected cross section the width of subsections, within the cross section, is defined in the user input file RDSPCS.DAT. The subprogram HYPROP calculates the hydraulic radius, mean depth, top width and conveyance of each user defined subsection. Then, using Manning's equation, the flow rate and mean velocity of each subsection is calculated. These hydraulic variables are further adjusted to conserve mass within the cross section. The mean depth at the downstream end of the subsections is estimated through calculating the mean depth over a width equivalent to the subsection width. This width is centered at the lateral location of the redd under simulation.

The results of the HEC-6 total sediment load calculations are refined through separation of the suspended and bed load fractions by comparing settling velocity and shear velocity values. The bed load is then laterally distributed, using a weighing scheme, within the cross section.

Separation of Suspended and Bed Load Fractions. The shear velocity is estimated at the redd site under simulation through a form of the Karman-Prandtl equation for the velocity distribution in turbulent flow near rough boundaries, Equation 1 (Rouse, 1946, p. 195).

$$U/U_* = 5.75\log_{10}(z/D_{90}) + B \qquad (1)$$

where

U_* = turbulent shear velocity (ft/s)

U = mean water flow velocity (ft/s)

z = mean depth at redd (feet)

D_{90}= Diameter of particles in bed for which 90% are smaller (feet)

B = a variable that accounts for both roughness and spacing and the aeration in turbulent flow

The settling velocity (V_p^i) of the geometric mean of each particle size fraction is compared with the shear velocity calculated using Equation 1. If $U_* \geq 0.8V_p^i$ then the particle is considered to be in suspension most of the time. If $U_* < 0.8V_p^i$ then the particle is considered to be a part of the bed load.

Lateral Bed Load Variability. After the total sediment load is separated into the suspended and bed load transport regions using the settling and shear velocity criteria described above the bed load is distributed laterally in the cross section. Each bed load particle size fraction is distributed based on the square of the unit discharge calculated for each user specified subsection (Eq. 2).

$$g_j^i = g^i \frac{q_j^2}{T_j \sum_{j=1}^{n} q_j^2} \qquad (2)$$

where

g = bed load transport rate (tpd/ft)

q = unit water flow rate (ft^3/s)

T = free surface width of subsection (feet)

i refers to the particle size fraction

j refers to the subsection

Armor Stability and Bed Movement. The Bed Stability Factor (BSF) calculate in HEC-6 is used as a criterium to trigger filling of the pit and removal of the

tailspill. Because a flow event large enough to move stream substrate into the pit would also likely remove the tailspill, pit filling and tailspill removal are assumed to occur simultaneously. Gessler (1977) suggested a BSF value greater than 0.65 to maintain stable armor. The user, however, may set this limit by adjusting the variable VBSFC in the input data. A second criterium that must be met to trigger filling of the pit and removal of the tailspill is related to the total bed load transport rate. When the BSF criterium is satisfied for armor movement the accumulated bed load moving into the pit must be sufficient to fill the pit volume. When this criterium is met the pit is filled in one day. The user may select the particle size distribution of the pit material from 4 different material compositions.

Redd Habitat

The reader is referred to documentation of the SIDO model (Alonso et al. 1988) for a description of the redd habitat. The redd domain was discretized for the purpose of solving the dispersion/advection equation using an alternating direction, implicit, finite difference method. A finite difference grid of 240 cells is used to represent the redd geometry in two dimensions (Alonso et al. 1988). The redd domain is divided into 4 compartments; the pit zone, the disturbed zone which overlays the egg pocket and the undisturbed stream substrate (Fig. I-3).

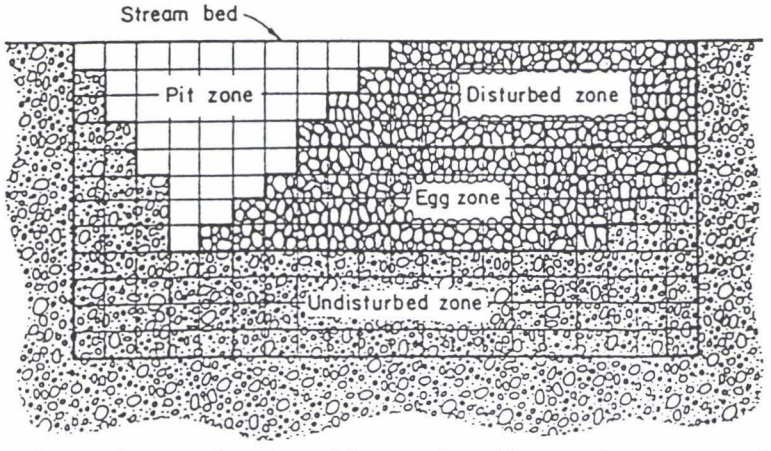


Figure I-3. Discretized Redd Domain (from Alonso et al. 1988)

Sediment and dissolved oxygen are moved into the redd through advection and/or gravitational settling, neglecting the smaller dispersive transport mechanisms. The model simulates oxygen consumption by sediment and eggs. Sediment is deposited in the substrate by filtering and by gravitational settling. The Einstein sediment intrusion mode is simulated using the Sakthivadivel criterium. To trigger seal formation in the Beschta sediment intrusion mode the Diplas and Parker criterium is employed. All cells in a disturbed portion of the redd domain are initially in a pass-through status where sediment does not accumulate.

The sediment particle size distribution, porosity, hydraulic conductivity, interstitial velocity, dissolved oxygen concentration, oxygen demand rate and blockage status of each finite difference cell is calculated for each time step. Sediment is only deposited in a cell in filling status. These filling cells are initially at the boundary of the egg pocket or disturbed zone and the undisturbed zone. When a cell's pore volume has been filled by intruding sediment the cell achieves blocked status and the next up-gradient cell begins to fill. Details of the modifications implemented in SIDO to simulate bed load intrusion into porous gravel are discussed below.

Einstein Intrusion Mode. Because the transport mechanisms for suspended sediment differs from bed load particles estimation of the boundary condition for the diffusion/advection equation calculations is also different. The simulation of suspended sediment intrusion (Alonso et al. 1988) was extended to consider sand and gravel size particles from bed load sources. Near bed suspended sediment concentration is discussed in Vanoni (1975) and others. To accommodate the intrusion of larger particles two sediment intrusion mechanisms are simulated, the Einstein intrusion mode and the Beschta intrusion mode. The Criterium for the Einstein intrusion mode (Sakthivadivel and Einstein 1970) states that particles will intrude to the bottom of a porus gravel if

$$14d_s^i < D_{50} \quad (3)$$

where

d_s^i = diameter (geometric mean) of intruding particle size fraction (mm)

D_{50} = as previously defined, referring to the gravel framework (mm)

Particle size fractions violating the criterium stated by Equation 3 are passed over the redd domain.

Bed Load Concentration. Calculation of the bed load sediment concentration at the boundary of the redd domain is based on the particle velocity (U_g^i) and a fitting variable, AVGPD, that reflects the range of particle motion orthoganal to the down-stream direction of motion. The particle velocity is estimated using relationships between water velocity and critical velocity for initiation of motion.

Kalinske (1942, 1947 in Vanoni 1975, P. 171) proposed the following relation for bed load particle velocity.

$$u_g = m(u_o - u_c) \quad (4)$$

where

u_g = velocity of sediment particle (ft/s)

u_o = instantaneous velocity of water in vicinity of the particle (ft/s)

u_c = critical velocity for initiation of movement of the particle (ft/s)

m = proportionality factor

Mavius and Laushey (1947 in Vanoni 1975, P. 103) further proposed that the critical velocity for initiation of motion of a particle may be given by;

$$u_o^i = 0.5(Sg_s^i - 1)^{1/2} d_s^{i(4/9)} \quad (5)$$

where

u_c^i = critical velocity for initiation of movement of the grain (ft/s)

d_s^i = particle diameter (mm)

Sg_s^i = particle specific gravity

Local velocity in the vicinity of a bed load particle can be found using the logarithmic velocity distribution (Rouse, 1946 p. 195)

$$u = \sqrt{\frac{\tau_o}{\rho}}\left[\frac{2.3}{K}\,\mathrm{Log}\left(\frac{y}{k_s}\right) + 8.5\right] \qquad (6)$$

where

ρ = fluid density (slug/ft^3)

K = von Karman coefficient for clear water (0.4)

y = local depth, taken as the elevation of the bed load particle above the bed virtual surface, taken as one particle diameter above the elevation of the virtual bed (feet)

τ_o = local shear stress (#/ft^2)

k_s = $0.5D_{50}$ (or some other particle size statistic of bed material, e.g. $0.5D_{90}$) a measure of bed roughness (feet)

Substituting Equations 5 and 6 into Equation 4 gives the velocity of bed load particle i.

$$U_g^i = m\left[\sqrt{\frac{\tau_o}{\rho}}\left[\frac{2.3}{K}\mathrm{Log}\left(\frac{y}{k_s}\right) + 8.5\right] - 0.5(S_g^i - 1)^{1/2} d_s^{i(4/9)}\right] \qquad (7)$$

The concentration of a particle size fraction, at the redd boundary, carried in the bed load (C_b^i) is estimated by:

$$C_b^i = \frac{q^i}{\gamma_w U_g^i d_s^i \mathrm{AVGPD} * 0.00328 + G} \qquad (8)$$

where γ_w is the specific weight of water, G is the total bed load rate and the other variables were previously defined.

Beschta Intrusion Mode. Simulation of the Beschta intrusion mode is based on the diameter statistics of the intruding bed load and the framework material. Development of a seal in the gravel framework occurs when intruding particles become trapped in the gravel interstices. These particles form a seal trapping finer intruding particles. A seal is triggered in the gravel framework when the bed load material particle size statistics meet Diplas Parker criterium and the total bed load mass is sufficient to create a seal of finite volume. The Diplas and Parker criterium (Diplas and Parker 1985) proposes that a seal will be created if

$$5D_{15}^{s} < D_{15}^{f} < 5D_{85}^{s} \qquad (9)$$

where

D_{15}^{s} = particle diameter for which 15% of the intruding sediment material is finer (mm)

D_{15}^{f} = particle diameter for which 15% of the gravel framework material is finer (mm)

D_{85}^{s} = particle diameter for which 85% of the intruding sediment material is finer (mm)

When the conditions stated by Equation 9 are met the bed load particle size distribution is appropriate for seal formation. A seal is triggered in one of the finite difference cells in the redd domain when sufficient mass of the appropriate particle size distribution has intruded. The sediment mass required for triggering a seal in a finite difference cell is estimated as follows.

$$M_s = THSEAL\gamma_s\gamma_w\Delta x \qquad (10)$$

where

M_s = solid mass of material required to trigger a seal (ft^3)

THSEAL = user defined thickness of seal, conceptually a solid mass of intruding material (feet)

Δx = longitudinal dimension of a finite difference cell (feet)

The depth of sealing in the gravel framework (DPSEAL) has been estimated by Diplas and Parker (1985), Beschta and Jackson (1979) and others to be in the range

$$DPSEAL = (2.5 \text{ to } 5)D_{90}^f \qquad (11)$$

The first cell in which a seal will be triggered, if the pit has not filled, is in the egg zone at the base of the pit area. Sealing progresses, as material is supplied, up the down stream face of the pit and onto the disturbed material deposit at a depth DPSEAL. If the pit has been filled, previous to seal development, a seal will be triggered over the redd, beginning at the upstream end, at a depth DPSEAL.

When a seal is triggered the finite difference cell is assigned blocked status and begins accumulating intruding sediment that meets the Sakthivadivel criterium (Eq. 3) and passes water and dissolved oxygen. The initial conditions for the sealed cell is given by the particle distribution in the appropriate redd zone at t = 0.

MODEL EVALUATION

The SIDO model was initially developed for a site on the Tucannon River in southwestern Washington, USA (Alonso et al. 1988). Sediment in the Tucannon

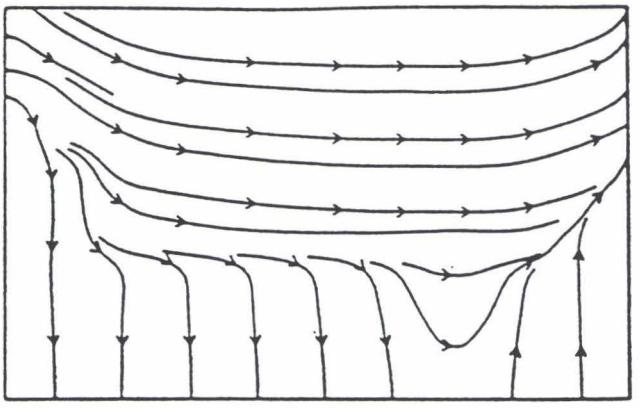
River is predominantly fine sands, silts and clays. Verification exercises showed that sediment intrusion by fine material was represented in a reasonable manner by SIDO. In agreement with field observations, filling of the redd gravel framework by fine sediment coincided with episodes of high flow and high suspended sediment load (Alonso et al. 1988). To extend the model's capabilities to simulate sediment intrusion in streams with high sand loads the model was modified to simulate intrusion of bed load material as described above. The following sections illustrate the predicted effects of sediment intrusion from bed load on the intragravel flow regime and evaluate model simulations of water temperature and dissolved oxygen concentration through comparisons with data from the South Fork of the Salmon River in central Idaho.

Seal Formation and Intragravel Flow Patterns

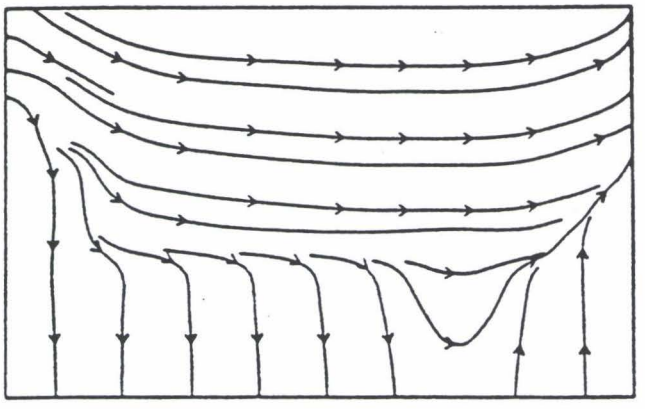
The seal formation mechanism implemented in SSAM was evaluated by simulating sediment intrusion into a chinook salmon redd over a 40 day time period during the rising limb of the spring snowmelt hydrograph of 1990. Three different sediment intrusion cases were simulated. The redd domain displayed at the top of Figure I-4 represents the case where the sealing mechanism has been defeated. The redd domain displayed in the middle represents the case where a seal is triggered at 3 times D_{90} of the disturbed zone and the bottom redd domain represents the case where a seal will be triggered at a depth of D_{90} of the disturbed zone.

Figure I-4 shows the simulated velocity streamlines in the redd at day 1 of the simulation period and Figure I-5 shows the corresponding filling status of the finite difference cells in the redd domain. The velocity streamlines are horizontal, in the pass through cells of the clean porous gravel framework. A slow leakage through the undisturbed zone underlying the redd is displayed by the vertical streamlines near the bottom of the redd domain. After 22 days of

NO SEALING MECHANISM



SEAL AT $3D_{90}$



SEAL AT D_{90}

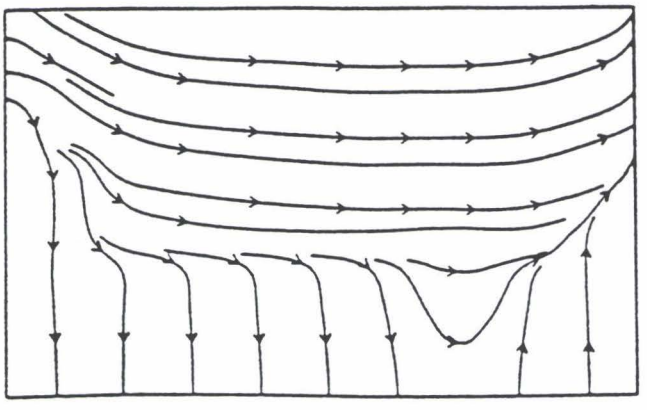


Fig. I-4. Intragravel Velocity Streamlines on Day 1 of the Simulation Exercise

NO SEALING MECHANINSM

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O O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B B O O O O O O O O O O O O O O O O O O
B B O O O O O O O O O O O O O O O O O F
B B B O O O O O O O O O O O O O O O O F B
B B B O O O O O O O O O O O O O O F B B
B B B O F F F F F F F F F F F F F F B B B
B B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B B
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SEAL AT $3D_{90}$

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O O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B B O O O O O O O O O O O O O O O O O O
B B O O O O O O O O O O O O O O O O O F
B B B O O O O O O O O O O O O O O O O F B
B B B O O O O O O O O O O O O O O F B B
B B B O F F F F F F F F F F F F F F B B B
B B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B B
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SEAL AT D_{90}

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O O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B B O O O O O O O O O O O O O O O O O O
B B O O O O O O O O O O O O O O O O O F
B B B O O O O O O O O O O O O O O O O F B
B B B O O O O O O O O O O O O O O F B B
B B B O F F F F F F F F F F F F F F B B B
B B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B B
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[O = pass-through cell, F = filling cell, B = Blocked cell]

Fig. I-5. Redd Filling Status on Day 1 of the Simulation Exercise

simulation (Figs. I-6 and I-7) sealing has started in the egg zone near the bottom of the pit. The reduced porosity and hydraulic conductivity of sealed cells results in deflected streamlines.

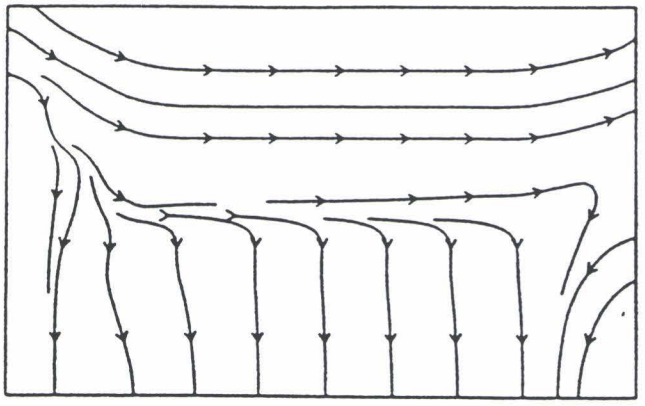
After 40 days of simulation (Figs. I-8 and I-9) the case without sealing shows filling of the redd domain by intruded sediment fines. Streamlines are deflected into the still empty pit zone and slow leakage through the bottom of the redd is displayed. The case where a seal was triggered at $3D_{90}$ shows similar streamlines to the no-seal case because intrusion by the Einstein mode at depth $3D_{90}$ coincided with seal formation. Because seal formation at D_{90} occurred before intrusion by the Einstein mode reached that elevation a zone of high porosity gravel framework was created below the sealed zone. Hence, a zone of higher permeability is shown by horizontal streamlines in the bottom chart of Figure I-8. The finite difference cell blockage status for the seal at D_{90} case (Fig. I-9) shows pass through cells underlying sealed (i.e. blocked) cells.

These simulations of seal formation were carried out to test the seal formation mechanisms implemented in the sediment intrusion model. Intrusion by the Beschta mode was not observed in the field study during the fall chinook egg incubation period of relatively low flow rates. Neither did model simulations predict seal formation in the study redds. The following sections describe the results of model calibration and evaluation using field data.

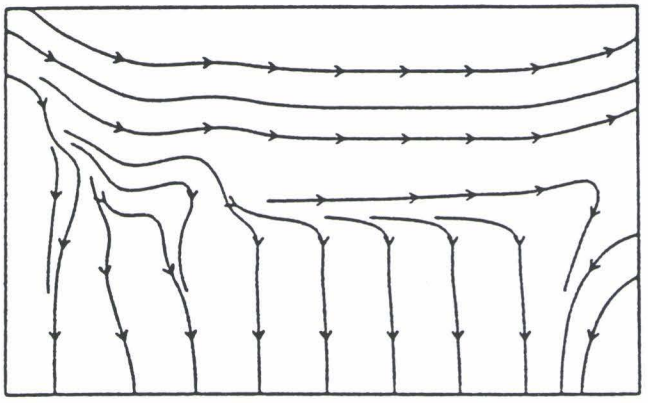
Field Site

The South Fork of the Salmon River (SFSR) in central Idaho is part of the Columbia River system. Formed in granitic material of the Idaho batholith, the river bed is largely gravel and fluvial deposits which are rich in sands and gravels. Weathering of native granite in the central Idaho batholith produces sediment loads largely in the sand size class (0.062 to 2.0 mm,

NO SEALING MECHANISM



SEAL AT $3D_{90}$



SEAL AT D_{90}

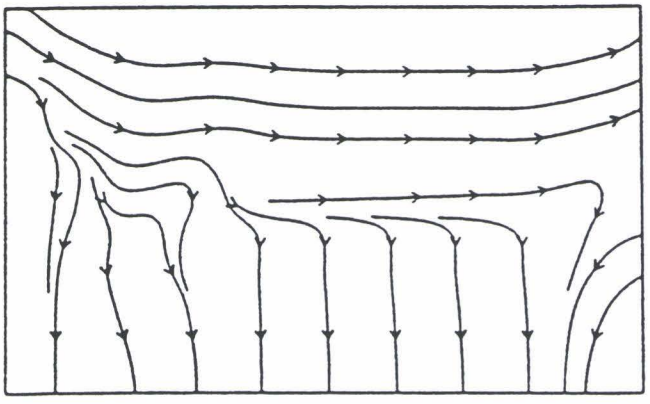


Fig. I-6. Intragravel Velocity Streamlines on Day 22 of the Simulation Exercise

NO SEALING MECHANINSM

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O O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B B O O O O O O O O O O O O O O O O O F
B B O O O O O O O O O O O O O O O O F B
B B B O O O O O O O O O O O O O O F B B
B B B O O F F F F F F F F F F F F B B B
B B B O B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
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SEAL AT $3D_{90}$

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O O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B B O O O O O O O O O O O O O O O O O F
B B O O O O O O O O O O O O O O O O F B
B B B O O O F O O O O O O O O O O F B B
B B B O O B O F F F F F F F F F F B B B
B B B O B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
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SEAL AT D_{90}

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O O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B O O O O O O O O O O O O O O O O O O O
B B O O O O O O O O O O O O O O O O O F
B B O O O O O O O O O O O O O O O O F B
B B B O O O F O O O O O O O O O O F B B
B B B O O B O F F F F F F F F F F B B B
B B B O B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
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B B B B B B B B B B B B B B B B B B B B
B B B B B B B B B B B B B B B B B B B B
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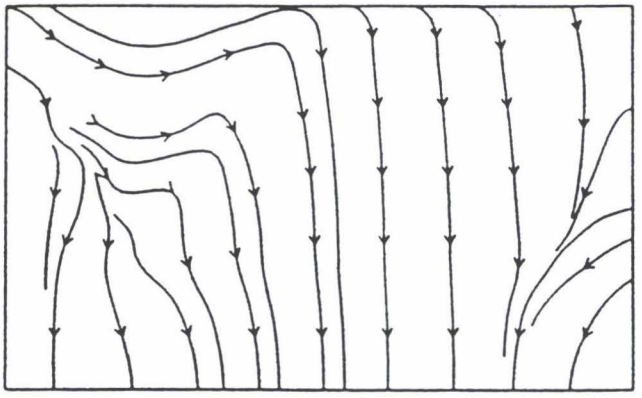
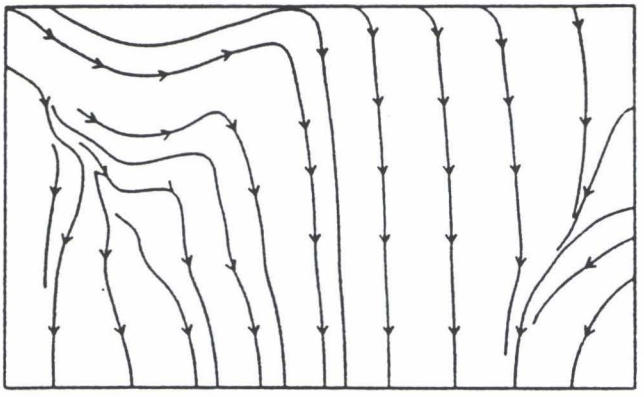
[O= pass-through cell, F= filling cell, B= Blocked cell]

Fig. I-7. Redd Filling Status on Day 22 of the Simulation Exercise

NO SEALING MECHANISM



SEAL AT $3D_{90}$



SEAL AT D_{90}

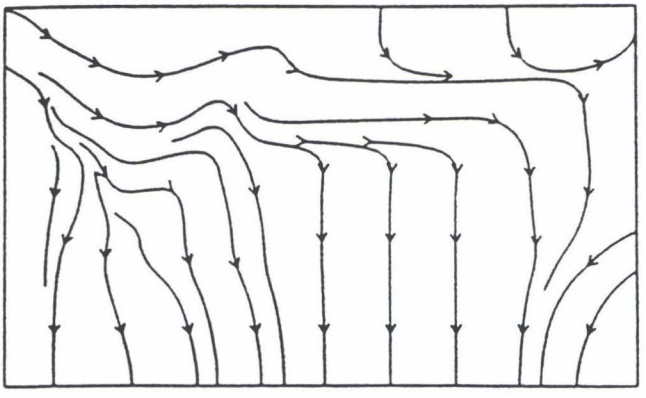


Fig. I-8. Intragravel Velocity Streamlines on Day 40 of the Simulation Exercise

NO SEALING MECHANINSM

O O O O O O O O O O F F F F F F F B B B
B O O O O O O O O B B B B B B B B B B B
B O O O O O O O B B B B B B B B B B B B
B B O O O O O B B B B B B B B B B B B B
B B O O O O O B B B B B B B B B B B B B
B B B O O O B B B B B B B B B B B B B B
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B B B B B B B B B B B B B B B B B B B B

SEAL AT $3D_{90}$

O O O O O O O O O O F F F F F F F B B B
B O O O O O O O O B B B B B B B B B B B
B O O O O O O O B B B B B B B B B B B B
B B O O O O O B B B B B B B B B B B B B
B B O O O O O B B B B B B B B B B B B B
B B B O O O B B B B B B B B B B B B B B
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B B B B B B B B B B B B B B B B B B B B

SEAL AT D_{90}

O O O O O O O O O O B B B B B B B B B B
B O O O O O O O O B B B B B B B B B B B
B O O O O O O O B O O O O O O O O O O O
B B O O O O O B O O O O O O O O O F B B
B B O O O O O B F F F F F F F F F B B B
B B B O O O B O B B B B B B B B B B B B
B B B O O B O B B B B B B B B B B B B B
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[O = pass-through cell, F = filling cell, B = Blocked cell]

Fig. I-9. Redd Filling Status on Day 40 of the Simulation Exercise

Dia.). The SFSR received high sand loading during the early 1960's because of the upland erosion of developed land during extreme climate events (Platts and Megahan, 1975) which impacted this important spawning and rearing habitat for anadromous fish.

The reach under study is about 1.5 km long and bank-to-bank distances average about 30 meters (Fig. I-10). The channel cross section geometry was measured at twenty three locations and a gaging station was installed and monitored at the reach outlet and at the confluence of a tributary. Sediment routing calculations employed these flow measurements as well as rating curves developed from suspended and bed load monitoring at the reach and tributary inlets and measurements of the stream substrate particle size distribution.

The period of study selected for analysis represents chinook salmon egg incubation from September 1990 to May 1991. This is a period of relatively low flow with a mean of 3.17 m^3/sec and a standard deviation of 2.44 m^3/sec. A field monitoring program designed to evaluate sediment intrusion included freeze coring (Everest et al. 1980) of artificial redds, post emergent chinook salmon redds and surrounding gravel substrate. Also, intrusion buckets (Lisle and Eads 1991) were installed and monitored.

The following sections describe the field measurements taken at the Poverty Reach study site and evaluation of the SSAMDR and SSAM models. The SNTEMP model was evaluated by comparing water temperature simulations with thermistor measurements taken at the water column/stream substrate interface. The HEC-6 model was evaluated by comparisons with water surface profile measurements and bed load and suspended load measurements which were taken at the reach outlet. The sediment intrusion model was calibrated using data from the intrusion bucket study. Measurements of water temperature and dissolved oxygen concentration in artificial redds containing chinook salmon eggs are used to evaluate simulations of water temperature and dissolved oxygen concentration.

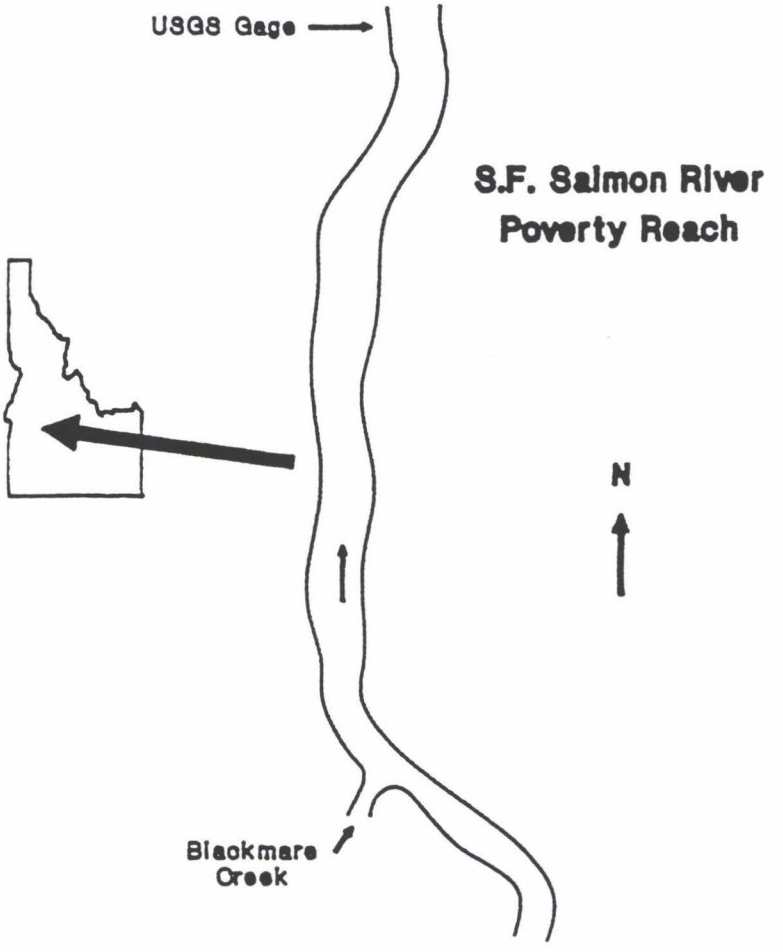

Fig. I-10. Location Map of the Field Study Site

Experimental Methods

Water Temperature. Meteorological data for the period of study were obtained from the weather station at the USDA-FS Krassel Ranger Station. A thermistor was implanted in the stream substrate near cross section 12, about mid way down the Poverty Reach. An automatic data logger recorded mean daily water temperature for the period August 29, 1990 to April 25, 1991.

River Mechanics. The HEC-6 model simulations employed 23 cross sections within Poverty Reach. The period of simulation for testing sediment routing calculations is the spring snowmelt hydrograph of 1990 (March 16 to July 31). Average daily flow rates and sediment load were measured on a tributary and daily flow and stage measurements were provided by a USGS gaging station at the reach outlet. Suspended sediment load was measured using a DH74 sampler and bed load was measured using a Helley-Smith 3.25 in. sampler. Thirteen sediment load measurements at the upstream cross section were used to develop a total sediment load rating curve. The HEC-6 model simulations of sediment transport were compared to 8 measurements of sediment transport at the reach outlet. In the sediment transport simulations, the initial bed gradation was estimated by a composite of 3 samples taken between 10 and 20 cm below the bed substrate surface.

Sediment Intrusion. The intrusion buckets were installed by excavating a 30 cm by 38 cm Dia. depression in the stream gravel substrate. A collapsed nylon bucket (40 cm by 30.5 cm Dia.) was placed in the depression and then filled with material larger than 6.35 mm. Chains, attached to the rim of the bucket, were left exposed on the substrate surface for later bucket removal and collection of the overlying material in the depression. At the end of the study period the particle size distribution of the material less than 6.35 mm was measured to determine the total mass and size characteristics of the sediment intruding the porous gravel.

The intrusion buckets were installed on August 30, 1990 and collected on May 14, 1991 after 258 days of exposure to sediment intrusion under field conditions. The finite difference grid used to represent the redd domain in SIDO was modified to simulate the geometry of the intrusion bucket experiments. With identical initial framework grain sizes, the lower half was assigned to the egg zone and the upper half was assigned to the disturbed zone. Thus, the porus gravel framework, subject to sediment intrusion, is rectangular in 2 dimensions and has a flat surface.

Redd Environment. Artificial redds were constructed in the vicinity of natural redds within the study reach. The redds were constructed using the technique described by Burton et al. (1989). Chinook salmon eggs (100) were inserted into the simulated egg pocket environment in each artificial redd. Water temperature and dissolved oxygen concentration were monitored through an access probe which was inserted into the vicinity of the artificial egg pocket during sampling. The probes consisted of a plastic well screen (approximately 5 cm Dia. and 30 cm long) with an access tube which extended to the stream substrate surface. Water samples were withdrawn, with a suction pump, from the egg pocket environment for temperature measurements and dissolved oxygen determination.

Results

Water Temperature. The SNTEMP model was calibrated to measurements by setting the global air temperature calibration constant to 0.91 and the calibration coefficient to 1.0. This produced a mean error of 0.0 for the period of study. A comparison of the thermistor measurements and model simulations (Fig. I-11) show reasonable agreement except during the winter months. The SNTEMP model does not simulate the effects of ice cover on water temperature. Hence, when air temperature rose, episodically, during periods of ice cover (eg. days 110 and 140) simulations indicate a rise in water temperature,

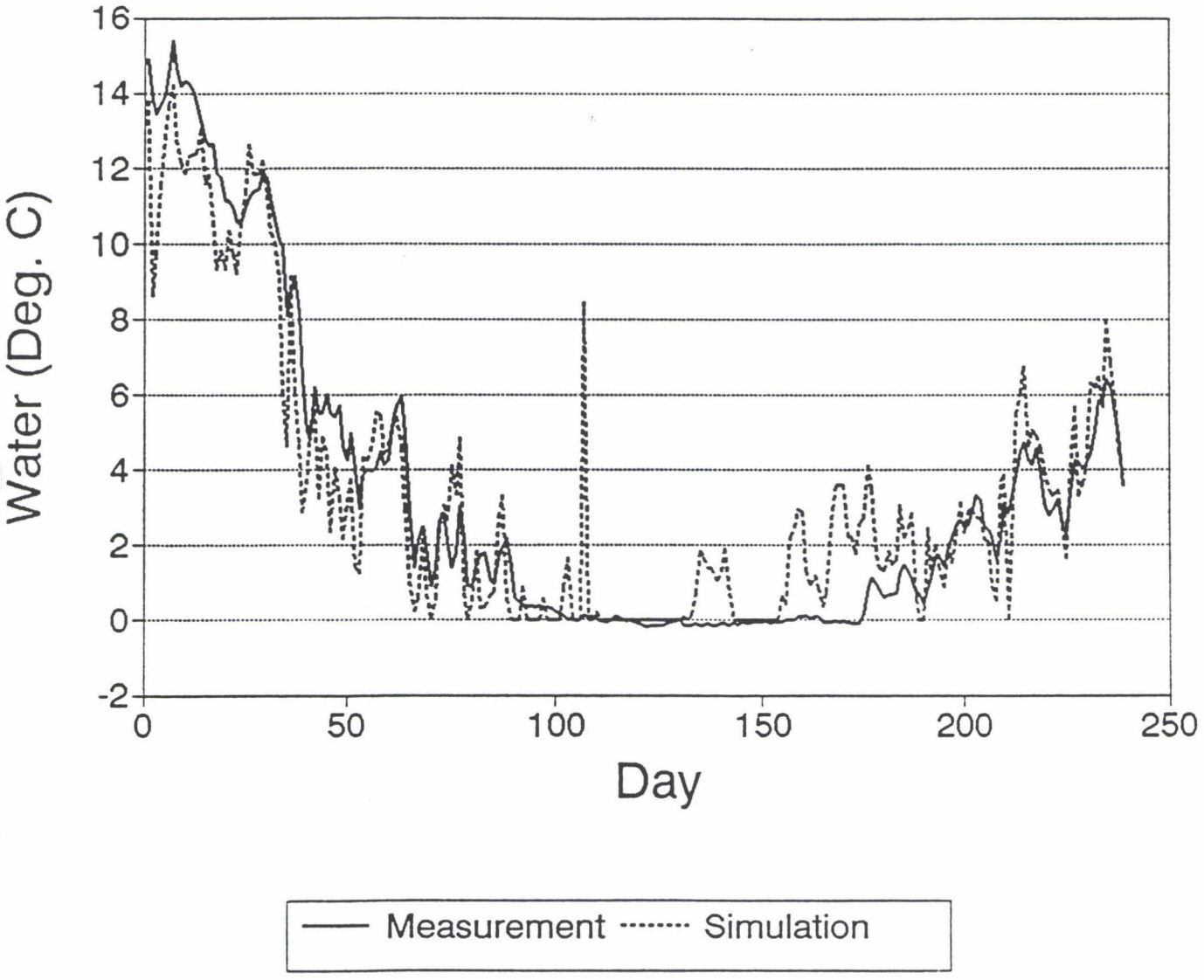

Fig. I-11. Comparison of Water Temperature Measurements and Simulations

whereas, the measurements do not.

River Mechanics. Figure I-12 shows the measured Spring snowmelt hydrograph used to verify HEC-6. Calibration of HEC-6 was necessary to determine the Manning n value for the Poverty Reach. A value of 0.05 provided a reasonable water surface profile when compared to field stage measurements where average water depth and thalweg elevation at each cross section is plotted along the longitudinal river profile (Fig. I-13). Additional comparisons of simulation and water surface measurements are presented in Appendix A. The discrepancy between measurements and simulations at about 2,500 feet was likely because of local perturbation of the flow in the vicinity.

In Figure I-14 total sand plus gravel load measured at the outlet cross section at Poverty Flat is compared to equivalent loads predicted by the model using the various transport capacity functions available in HEC-6 version 3.2. The HEC-6 model tended to over estimate sediment transport during low flows and to under estimate sediment load at higher flows. Silt transport simulations showed similar trends to sand transport at the field scale.

The stream shear velocity method for separating bed and suspended sediment load was tested by comparison of HEC-6 simulations, using the Toffaletti transport capacity formula, and field measurements at the reach outlet (Table I-1). Total sediment load calculations compare favorably with field measurements having a maximum difference of approximately a factor of 2 (julian day 136). Considering the variability of field measurements and the approximations used in calculating bed and suspended sediment load the maximum difference between bed load rates of about one order of magnitude (julian days 143 and 151) is considered acceptable.

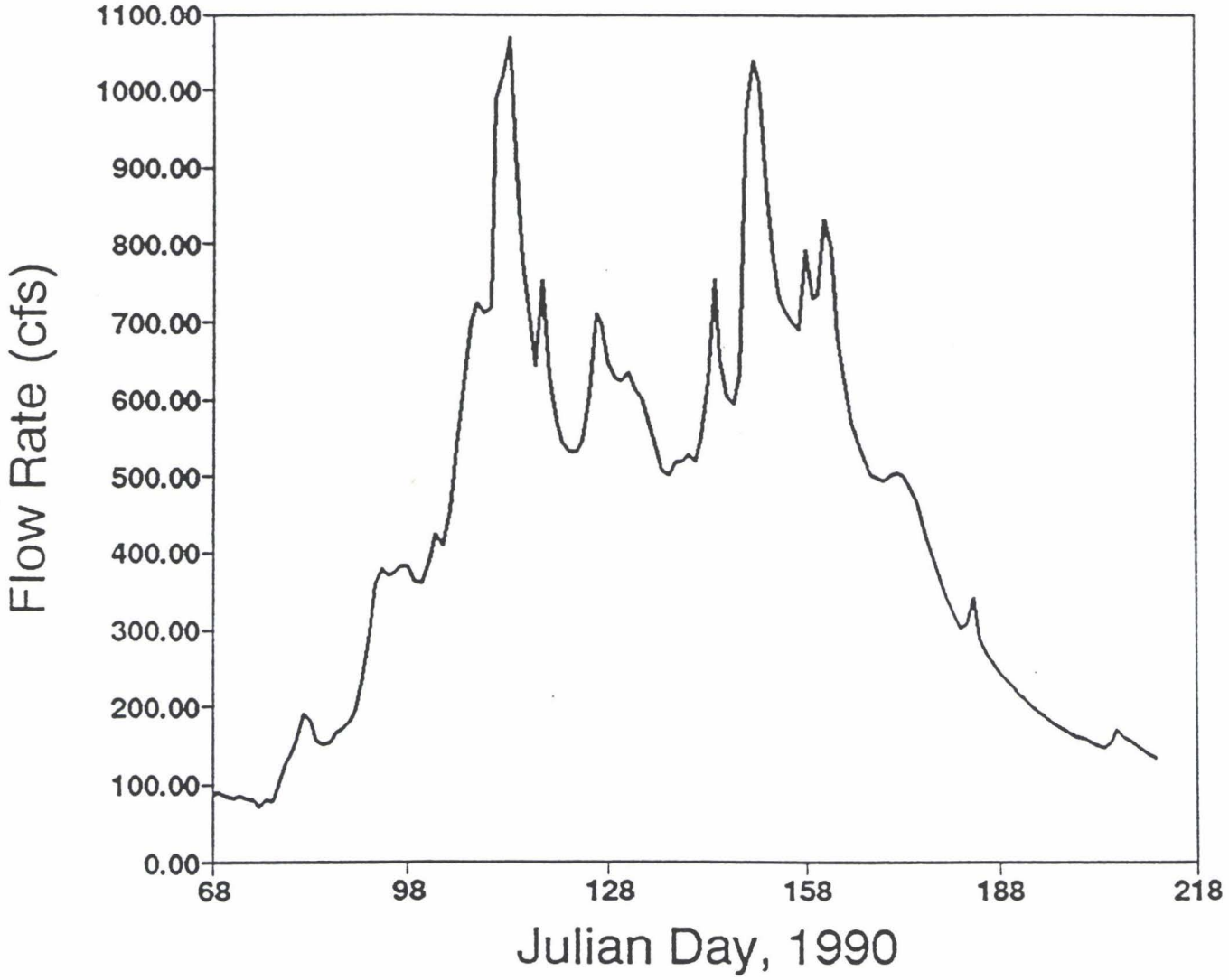

Fig. I-12. Spring Snowmelt Hydrograph used in the Verification of the HEC-6 Model of River Mechanics

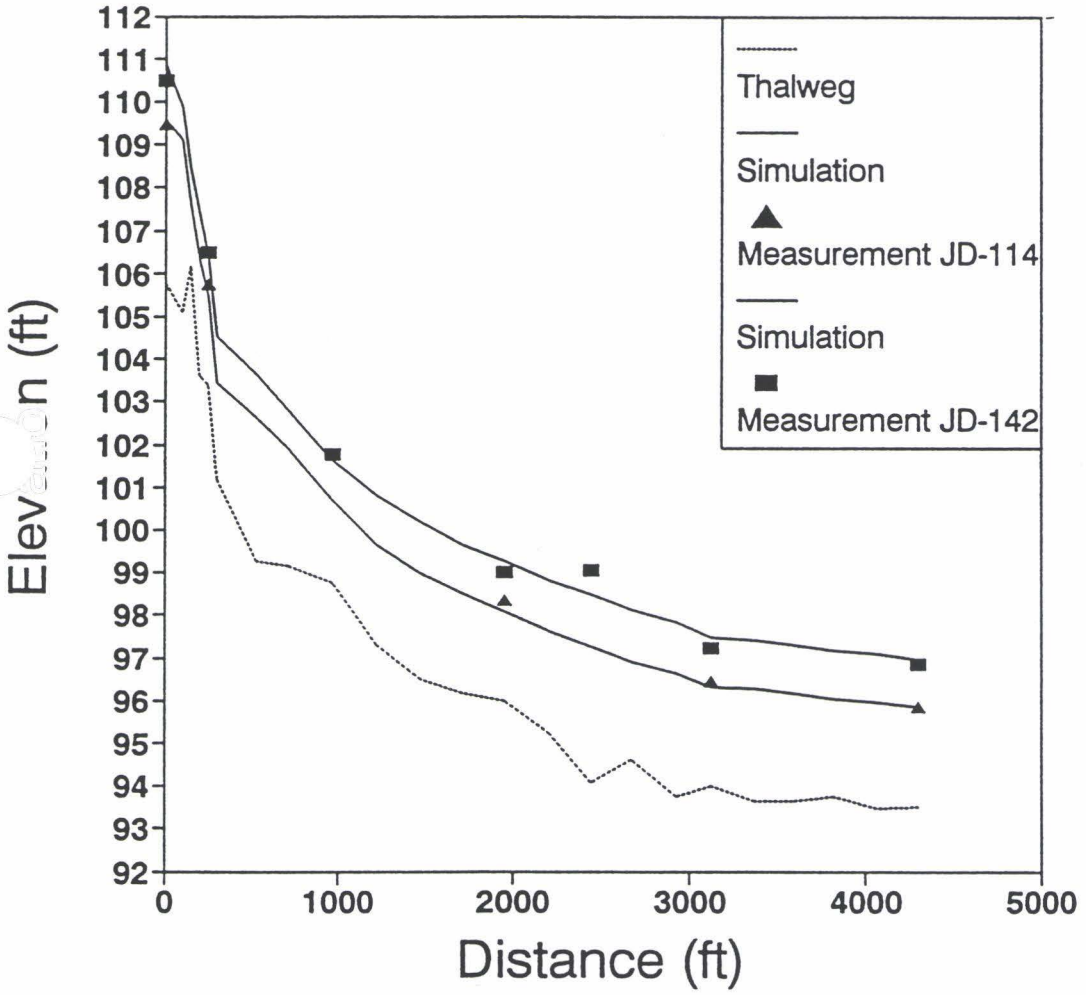

Fig. I-13. Comparison of Simulated (HEC-6) and Measured Water Surface Profiles

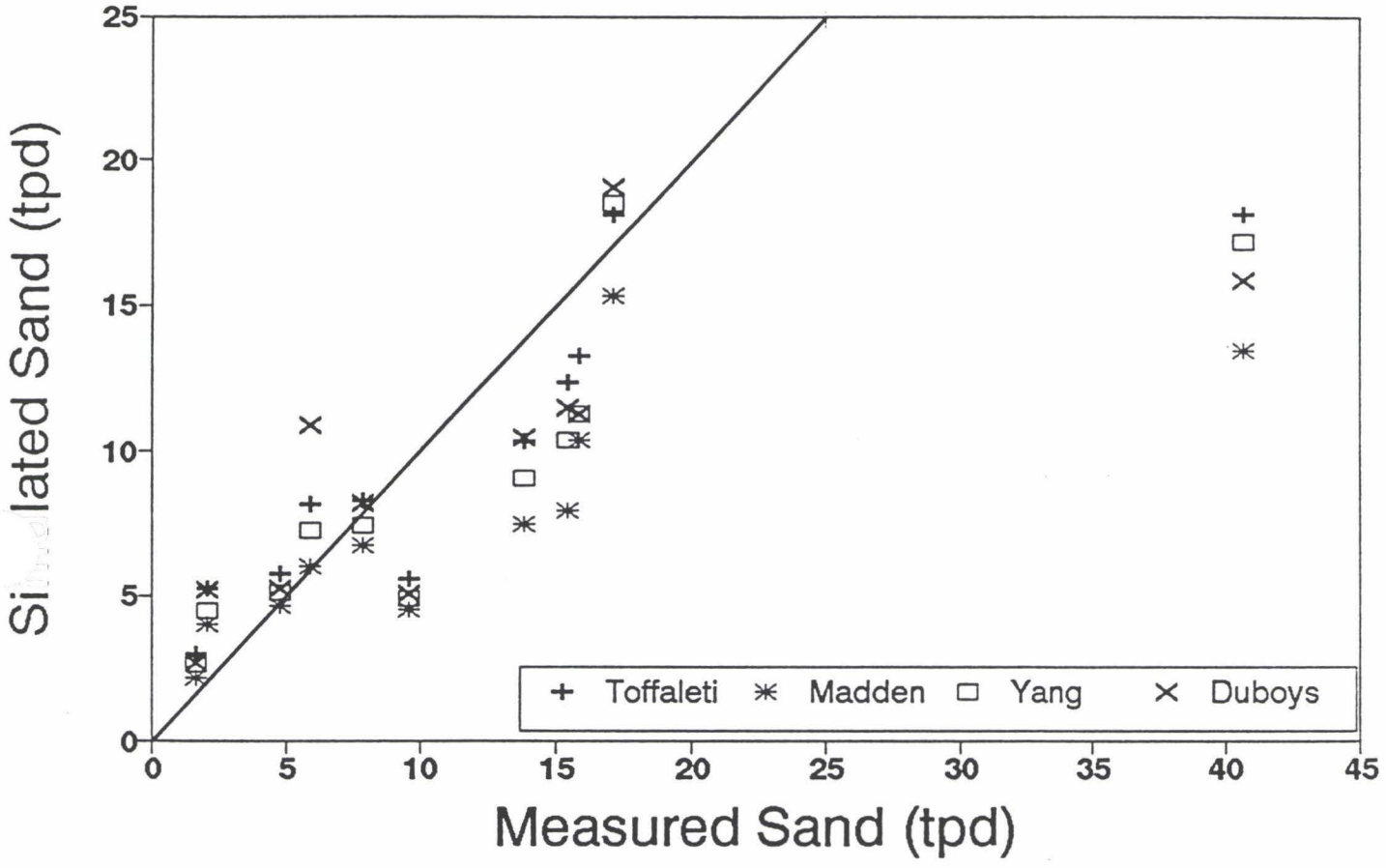

Fig. I-14. Comparisons of Measured and Simulated Sand and Gravel Load Using the Transport Capacity Functions in HEC-6, Version 3.2

Table I-1. Comparison of sediment load measurements and simulations (tpd) using the modified HEC-6 model.

J-DAY	Q	TOTAL		SUSPENDED		BED	
	(cfs)	Measured	HEC-6	Measured	HEC-6	Measured	HEC-6
107	738.1	34.84	19.48	33.94	15.94	0.92	3.54
115	795.8	41.7	26.51	35.36	19.11	6.34	7.4
123	509.1	15.57	12.02	13.85	10.82	1.73	1.2
128	673.3	13.66	16.94	10.57	14.2	2.62	2.73
136	453.8	4.92	11.79	4.69	10.18	0.23	1.61
143	542.6	14.32	18.53	13.79	13.8	0.53	4.73
151	1008.7	33.04	32.85	26.74	26.97	6.3	5.87
158	795.3	31.09	29.52	27.24	19.33	3.85	10.19

Sediment Intrusion. Model simulations and field data are presented in terms of the fraction, by weight, of intruded material in a unit volume of substrate. This is the cumulative mass of sediment intruding the porous gravel framework divided by the original gravel framework mass. Under the relatively low flow regime of the study period, particle sizes in transport were too small to initiate sealing of the gravel interstices. Hence, the Einstein intrusion mode prevailed.

The sediment intrusion model was calibrated using the variables CBADJ and AVBPV to adjust the suspended load and bed load concentrations at the boundary of the redd domain. Table I-2 compares fractions of all material finer than 6.35 mm (total sediment) and material finer than 0.063 mm (silt and clay) measured in the intrusion bucket gravel samples at the end of the study period to sediment intrusion simulations. Model predictions show general agreement with field measurements.

Table I-2. The measured and simulated fraction of fines (mass fines/mass gravel framework) intruding into individual intrusion buckets over the study period

Site	Fraction Fines			
	Total		Silt and Clay	
	Measured	Simulated	Measured	Simulated
I-1	0.1402	0.0295	0.00209	0.00219
I-2	0.1454	0.0465	0.00239	0.00201
I-3	0.1094	0.0478	0.00168	0.00269
I-4	0.0794	0.0949	0.00103	0.00261
I-5	0.1485	0.1250	0.00232	0.00246
I-6	0.1458	0.0691	0.00299	0.00196
I-7	0.0577	0.1848	0.00388	0.00219
I-8	0.1338	0.2344	0.00169	0.00265
I-9	0.1636	0.1960	0.00305	0.00235
I-10	0.0585	0.1532	0.00269	0.00278
Mean	0.1182	0.1181	0.00238	0.00239
Std. Dev.	0.0395	0.0716	0.00082	0.00029

The mean cumulative total sediment intrusion is displayed by the dark line in Figure I-15 along with the 95% confidence interval (light lines) and field measurement statistics. The increase in sediment intrusion rates during the last month of the study period is because of increased bed load rates associated with the beginning of the Spring hydrograph. Figure I-16 shows that the effect of the Spring smowmelt hydrograph on the intrusion pattern of the wash load is relatively small.

As was shown in the Tucannon River study (Alonso et al. 1988) fine sediments have a significant impact on average intragravel flow velocities. Figure I-17 shows the mean, and 95% confidence interval, of the interstitial velocities calculated in the bottom half of the intrusion bucket domain.

A comparison of Figures I-15 and I-17 shows that after 20 days interstitial velocities in the bottom half of the intrusion buckets drop by 65% in response to a 4% increase in the fraction of intruded fines. After the initial rapid drop, small fluctuations occur in response to changes in flow rates (i.e.

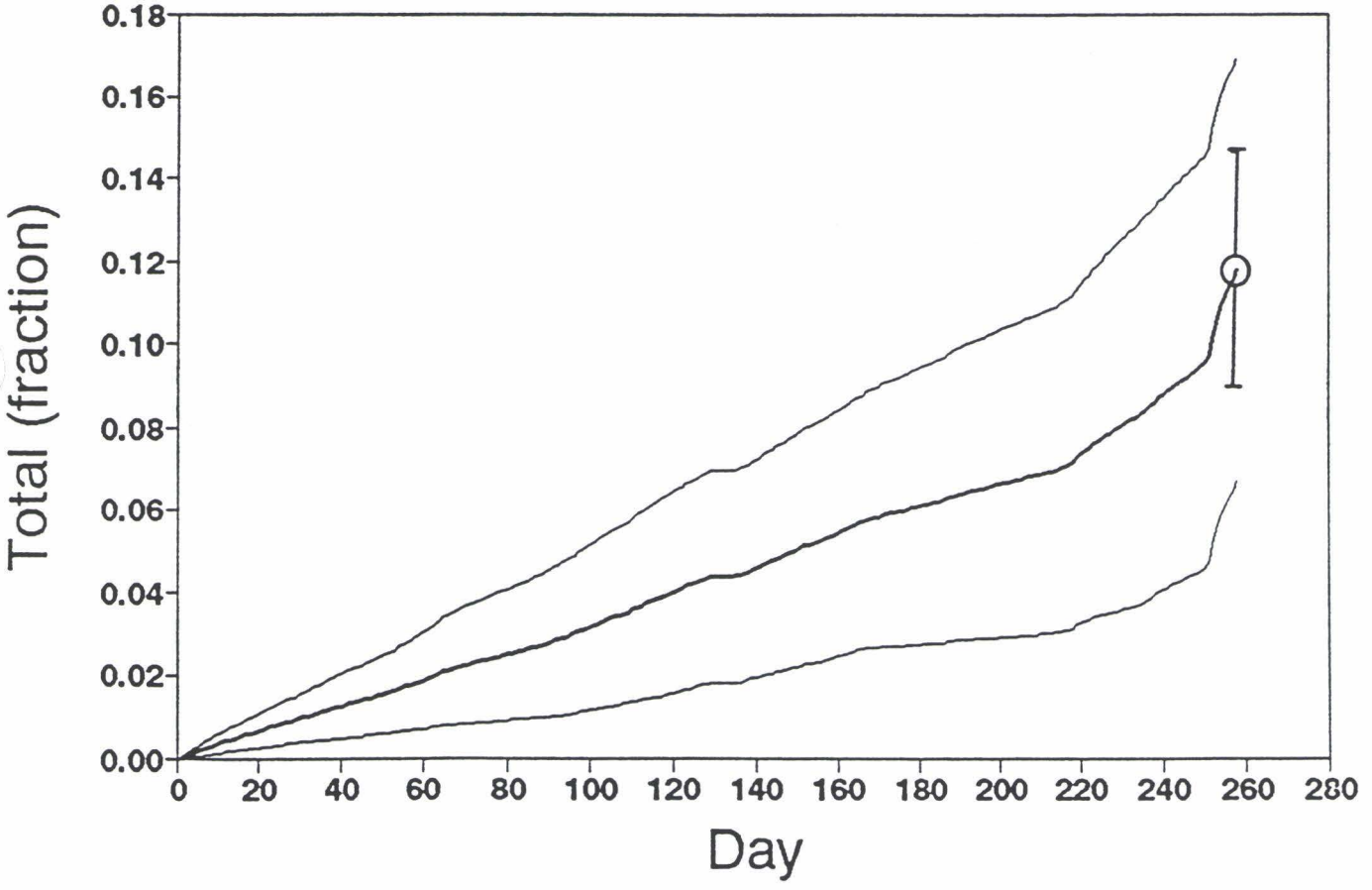

Fig. I-15. Mean and 95% Confidence Interval of Total Cumulative Sediment Intrusion in the Intrusion Bucket Study

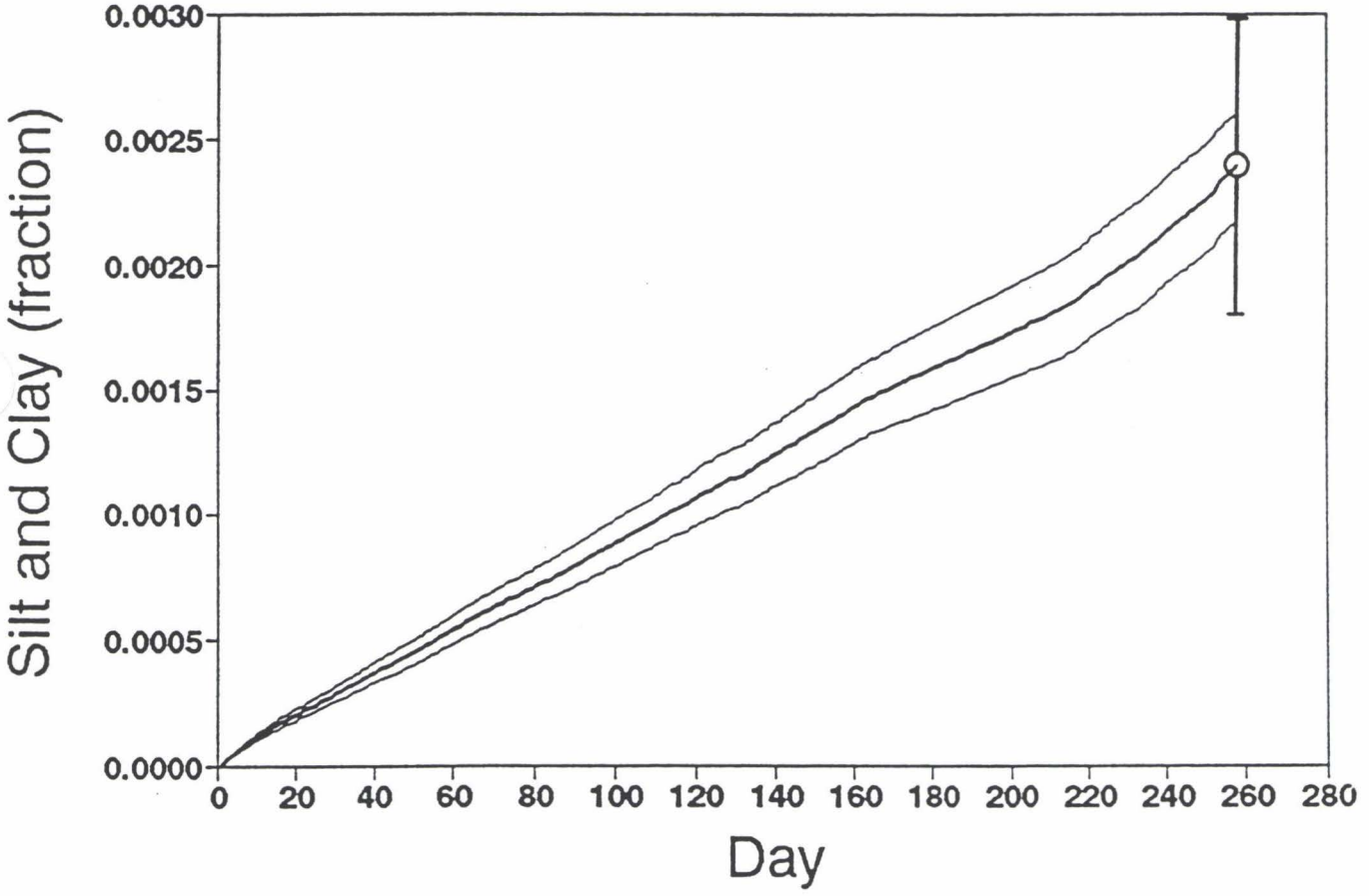

Fig. I-16. Mean and 95% Confidence Interval of Cumulative Clay and Silt Sediment Intrusion in the Intrusion Bucket Study

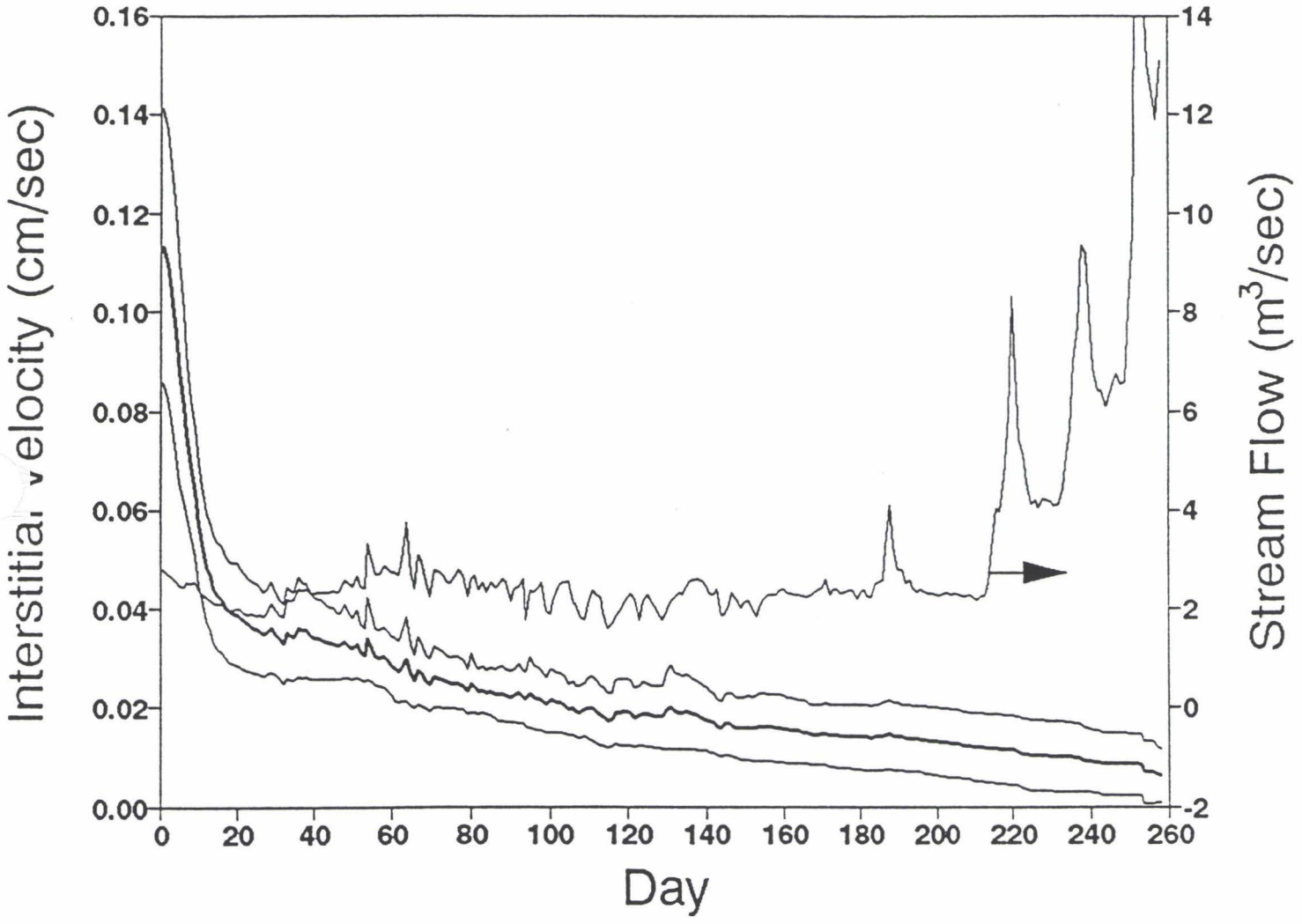

Fig. I-17. Mean and 95% Confidence Interval of Interstitial Water Velocity in the Bottom Half of Intrusion Buckets. The Stream Flow During the Study Period is Also Shown

water surface profiles), which affect the hydrodynamic pressure gradients driving intragravel circulation. As the gravel is filled with intruding fines, towards the end of the study period, the average interstitial velocities in the lower portion of the computational domain appear relatively insensitive to the rising limb of the spring hydrograph.

Redd Environment. Simulations of the artificial redd environment employed particle size distributions in the egg pocket estimated by Platts (1978) for Poverty Reach. The particle size distribution of the undisturbed zone was estimated in 1990 by sampling the substrate at a depth of 10 cm. The egg pocket was modeled having an egg count of 100 and dimensions characteristic of chinook salmon. The 10 artificial redds were simulated over the duration of the study period (August 30, 1990 to May 14, 1991). An example of model simulations of water temperature and dissolved oxygen concentration and field measurements (Fig. I-18) shows good over all agreement. Additional simulations for other artificial redds can be found in Appendix A.

SUMMARY

Sediment loading from anthropogenic sources adversely affects salmonid spawning habitat by silting the porous gravel egg nest or redd. The Salmonid Spawning Habitat Model (SSAM) simulates the effects of gravel siltation on salmonid spawning success. The model represents the major hydraulic processes driving gravel siltation on a field scale. The model simulates sediment and water flow and water temperature within a river reach. Within the redd environment the model simulates sediment intrusion and particle size composition over time. Model results show water temperature and dissolved oxygen concentration (DO) calculated for the redd environment. The user may use these results to observe occurrences of egg mortality caused by high water temperature (above 18 degrees Celsius) or low dissolved oxygen (below 2 mg/L). Percent fry emergence is calculated by the model and is based on particle size

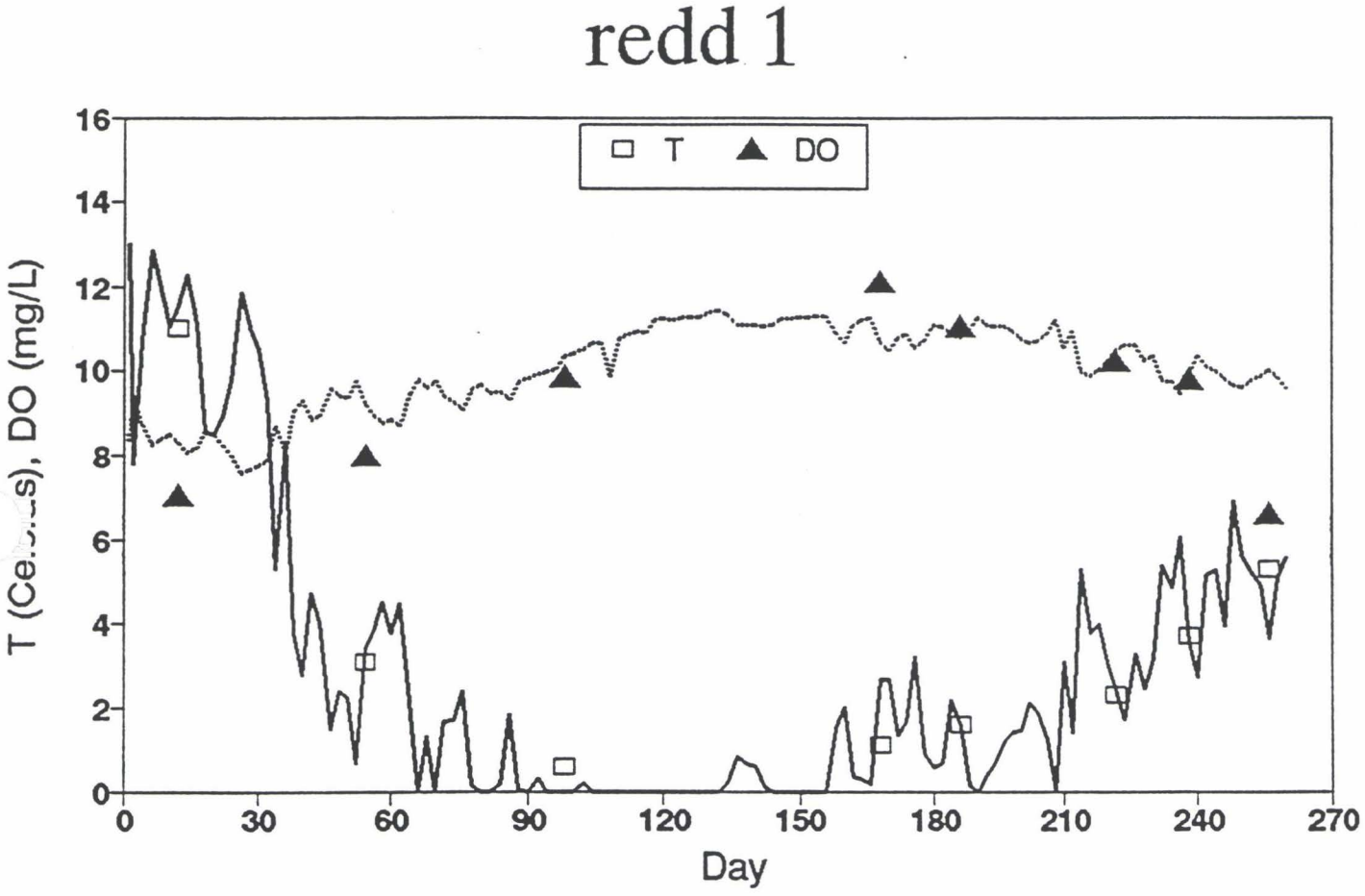

Fig. I-18. Model Simulations of Water Temperature and Dissolved Oxygen are Compared to Measurements Taken in Artificial Redd Egg Pockets Containing Hatchery Eggs.

distribution within the egg pocket (Theurer and Miller 1986) and does not consider water temperature or dissolved oxygen concentration.

Model comparisons with a field study program using intrusion buckets showed that the mean sediment intrusion mass can be accurately represented through adjusting two calibration variables. One variable adjusts the bed load and another adjusts the suspended load sediment concentration at the boundary of the redd domain. The calibrated model predicted dissolved oxygen concentration in artificial redds containing hatchery eggs with reasonable accuracy. The results presented here are preliminary and further model testing at different geographical sites is necessary for further model verification.

Future laboratory scale mechanistic studies are needed to understand the process involved in seal formation as sediment intrudes porous gravels. The mechanisms used to trigger seal development (Beschta intrusion mode) are rudimentary and more detailed methods are computationally intensive. In addition to adequately representing mean sediment intrusion, the model provided a reasonable estimate of the variability shown by the field data. This variability in the simulations arises from the quasi two-dimensional representation of hydraulic geometry and bed load rates incorporated into the HEC-6 sediment routing methodology. Model users should find this adaptation of the one-dimensional HEC-6 model gratifying when applications involve stream lateral variability and model computational efficiency is important.

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USERS GUIDE

INTRODUCTION

The SSAM model simulates the effects of stream hydraulics and water temperature on the physical and biological conditions in salmonid spawning habitat. The model requires specific information, either measured or synthetic, on river hydraulics and local meteorological conditions. These hydrologic data, used to drive SSAM, are generated by the SSAMDR program. A major limitation of the model, as a management tool, is that water and sediment flow are not driven by upland watershed processes and must be specified within the river reach of interest.

The following sections are designed to assist the user in use of SSAM which is a model package consisting of three integrated computer programs. These computer programs, HEC-6, SNTEMP and SIDO, are stand-alone models which have been integrated to provide a generalized representation of salmonid spawning habitat. The capabilities and limitations of the individual programs are summarized below and the details are described elsewhere. The original, not modified, model limitations apply to the integrated model system except for specific changes which are identified below. Details on the specific modifications are given in the section on mathematical development.

Model Capabilities and Limitations

Scour and Deposition in Rivers and Reservoirs (HEC-6, version 3.2), U. S. Army Corps of Engineers, Hydrologic Engineering Center. HEC-6 is a one-dimensional steady flow model which fixes the movable and immovable portions of the bed at each cross section for the duration of the simulation. The entire movable portion of the bed is adjusted vertically to reflect agradation or degradation. Modifications to HEC-6 were implemented, as follows, to adapt

the model to conditions encountered in gravel bedded rivers.

1. The user may define as many as 5 subsections, in the lateral direction, within as many as 8 cross sections in a river reach. Hydraulic variables (flow depth, hydraulic radius and conveyance) are calculated for each subsection. Depth is calculated at redd locations between cross sections for specified subsections.

2. The total load of each particle size fraction at redd locations, between cross sections, are calculated through longitudinal interpolation.

3. The total load of each size fraction is apportioned into suspended and bed load fractions based on shear velocity at each redd site.

4. Bed load rates are weighted laterally between subsections based on the square of the unit discharge.

5. The volumetrically weighted mean water temperature of the reach is updated daily from SNTEMP for use in sediment transport calculations.

Instream Water Temperature Model (SNTEMP), U. S. Fish and Wildlife Service. The SNTEMP model simulates instream water temperature using historical or synthetic hydrological, meteorological and stream geometry data. The model accommodates a wide range of stream network complexity. Modifications to SNTEMP were implemented, as follows, to adapt the model to conditions encountered in gravel bedded rivers.

1. The free surface stream width calculated by HEC-6 is updated in SNTEMP on a daily basis for each cross section in the reach.

Sediment Intrusion Dissolved Oxygen Model (SIDO), U. S. Department of Agriculture, Agricultural Research Service. Modifications to SIDO were implemented, as follows, to adapt the model to conditions encountered in gravel bedded rivers having significant bed load transport.

1. The following SIDO input data are generated by HEC-6 and SNTEMP.

   a. water and sediment flow
   b. water temperature
   c. channel geometry and bed substrate composition

2. Mobilization of bed substrate, and filling of the pit, is triggered by the Bed Stability Factor (BSF) criterium calculated in HEC-6. Gessler (1970) suggested a BSF of equal to or greater than 0.65 for a stable armor layer. However, the user may specify the BSF value for triggering filling of the pit and tailspill removal in the input data.

3. Intrusion of sediment from bed load sources is simulated. Redds are positioned laterally in the river bed subject to the sediment loading calculated for the subsection.

4. The Beschta intrusion mode is simulated when appropriate conditions occur.

5. In one model simulation run 40 redd sites may be evaluated. Eight cross sections may be considered with 5 redds below each cross section.

Modes of Operation

The software for HEC-6 and SNTEMP were modified for the specific purpose of building an input data set to drive the execution of SIDO. However, output

verification data from HEC-6 and SNTEMP may be obtained by following the instructions contained in the original documentation (HEC 1977, Theurer et al. 1985)

Units

The units of measure employed in the stand-alone software versions of HEC-6 (particle diameters (metric), all others (U. S. standard)), and SNTEMP (metric) are also employed in SSAM. Units used in SIDO are U. S. standard for elevations and distances (ft) and metric for particle sizes (mm).

Software and Hardware Requirements

Because SSAM is a confederation of fortran models developed over the past 20 years the code, as a whole, is an amalgamation of early and improved FORTRAN programming conventions. The HEC-6 model was initially developed by W. A. Thomas of HEC as an extension of his OZARK SEDIMENT MODEL developed at the Little Rock District Office of the Army Corps of Engineers. HEC-6 version 3.2 was modified in October of 1986 to include FORTRAN 77 upgrades. The SNTEMP model is a synthesis of FORTRAN 77 programs. The heat transport module (TRNSPT) which is directly linked with HEC-6 was last updated in January 1987. The SIDO model, was originally developed in 1988 and was written in standard ANSI FORTRAN 77. The SSAMDR and SSAM models were developed on a DEC VAX 4000 computer system. The SSAMDR executable code requires about 162 K and the SSAM program about 54 K of memory.

DATA REQUIREMENTS

The user input required by SSAM, in addition to the input required by HEC-6 and SNTEMP, consists of the unformatted data file, SSAMIN.BIN, generated by SSAMDR and two formatted data files. The two formatted data files control 1) the temporal limits and the simulation and output options and 2) the geometry, particle size distribution and simulation specifications for individual redds.

Job Control Data

The user must specify the simulation time spans for both the generation of the redd data using SSAMDR and in redd habitat simulations using SSAM. A long time interval should be generated in SSAMDR to drive the redd habitat model. Then, in redd habitat simulations the user may draw on the input data as needed in simulations of any time span within the time horizon simulated in SSAMDR. In the job control data file the simulation time definition is specified by the beginning julian day during the first year of simulation and the total number of days of simulation.

The simulation options available in SSAM are similar to the options available in SIDO. The option designation numbers have not been changed from those in SIDO but the steam flow options are not available. Users are referred to the HEC-6 users manual for a detailed description of the stream flow and sediment transport simulation and output options. The options available in SSAM are given in Table II-1.

Table II-1. Simulation Options Available in SSAM

OPTION	LEVEL OF SIMULATION
0	not used
1	not used
2	calculate intragravel flow and dissolved oxygen
3	calculate intragravel flow and sediment intrusion
4	calculate all of the above

The output modes available in SSAM are also similar to those available in SIDO, except that the stream flow output and plotting capabilities are not programmed. The output modes available in SSAM are displayed in Table II-2.

Table II-2. Output Modes Available in SSAM

MODE	OUTPUT PRODUCED
0	no output
1	not used
2	table of pressure head distribution within the redd
3	tables of effective porosity and hydraulic conductivity with the redd
4	tables of interstitial velocity distribution within the redd
5	tables of clay, silt and sand distribution within the redd
51	table showing filling status of redd
6	tables of dissolved oxygen distribution within the redd
7	all tables
8	verification summary table

HEC-6 Data Requirements

A detailed description of the data requirements for HEC-6 are provided in the HEC-6 Users Manual (1977). The four basic data sets required are channel geometry, sediment load data, hydrologic data and operating rule data.

Geometric data includes cross section stations and elevations, reach lengths, Manning n value(s) and, limits on the movable bed and ineffective flow areas. A sediment rating curve (water flow vs sediment load) is required for the reach upstream boundary and any significant tributaries entering the reach. A stage discharge relationship for the reach outlet may employ either a rating curve or discrete stage values. The stage discharge relationship in combination with the time step and temperature cards is recommended for SSAM simulations. As in all other modules in SSAM, a daily time step is used.

SNTEMP Data Requirements

The general data input requirements for the SNTEMP model are a description of the stream geometry, meteorological data and hydrological data. Details on data acquisition and format can be found in the User's Manual of the Instream Flow Information Paper No. 16 (Theurer et al. 1984).

The stream geometry data describes the stream network system under consideration. These data consist of a description of the stream skeleton network and geometry information such as latitude and elevation above mean sea level. An optional shade data file incorporates geographic and riparian shading effects into the radiative heating calculations. Hydrologic information includes flow rates as well as source water temperatures. A zero discharge source may be used at headwater locations if source water temperatures are unknown. Mean air temperatures, adjusted for elevation, then drive source water temperature. The most representative meteorological data for the vicinity should be obtained through local sources or sources described in Theurer (1984) and Bartholow (1989).

Redd Physical Description and Simulation Variables

The redd description data provides information locating each of the redd sites of interest within the spawning reach and the physical and simulation parameter information needed to calculate the intragravel habitat for each redd. The SSAMDR program uses the geometry information provided for each redd to produce the water and sediment flow and water temperature information needed for redd simulations in SSAM. Calculations in SSAM then draw on the hydraulic information provided by SSAMDR and the redd physical data provided by the user.

Some general information about the spawning reach of interest includes the

mean elevation above mean sea level and the total number of cross sections associated with redds. Two additional variables affecting intragravel circulation are global for all redds under simulation. One adjusts the intragravel settling velocity of the sand size particles and the other is a logical flag that calls for all finite difference cells in the undisturbed zone be assigned blocked status at the beginning of the simulation.

Detailed information is also required about the position of specific redds in the reach, the characteristics of the spawning gravel and variables controlling the intragravel circulation. These variables are discussed below.

Cross Section and Subsection Information

Because redd locations are defined with respect to upstream cross sections the user must specify the total number of cross sections used to locate redds in the reach. Additionally, the elevation of the spawning grounds must be provided. The following information for each cross section must be input by the user.

1) The sequential number of each cross section, counting from the upstream end to the outlet, as input to HEC-6.

2) The number of break points in each cross section.

3) The number of redds sites of interest below each cross section of interest.

4) The number of user defined subsections for each cross section of interest.

5) The user may set a flag (IREID) to specify that all the redds in

the cross section have identical physical characteristics.

6) The following information locates redds, geometrically, in the spawning reach.

   a) The distance, looking down stream, from the left end of the upstream cross section.

   b) The orthoganal distance from the down stream cross section.

   c) The subsection containing the redd of interest.

7) Each break point (up to 100 break points in each cross section may be identified) in the cross section may be associated with a subsection using the integers 1 to 5.

Description of the Spawning Gravel

The specific gravity of all the particles used in the simulation (from clay to small boulders) is used in model calculations. The user must supply the mass cumulative fraction of the particle sizes present in the all three zones within the redd domain. The model is capable of simulating 18 particle size fractions in the redd domain and 15 particle size fractions in transport. Particle size statistics (D_{15}, D_{50} and D_{90}) for the disturbed and egg zones are required for triggering seal formation in the redd gravel framework. Details on the criteria for triggering seal development are given in Chapter xx section xx.

As discussed above filling of the pit and removal of the tailspill is triggered when the calculated BSF is less than a user specified limit and the

bed load is of sufficient mass. The user may also specify the particle size composition of the material filling the pit.

Variables Controlling Intragravel Circulation

The intragravel flow variables are discussed in Alonso et al. (1988). Additional variables used in SSAM, are a variable to adjust the bed load material concentration at the redd/stream substrate interface (AVGBPV), and a variable that multiplies the settling velocity of sand and larger size particles to account for the reduced velocity in the intragravel environment (SWSADJ). Calibration exercises suggested values of 0.013 for AVGBPV and 0.001 for SWSADJ. These variables are constant for all redd sites.

Variables controlling seal development in the gravel framework include the depth of the seal (DPSEAL), which is a user input variable that multiplies the D_{90} of the disturbed or egg zone. The product of D_{90} and DPSEAL defines the depth of the seal from the surface of the disturbed zone. The thickness of the seal (THSEAL) is a user input variable controlling the mass of material required to trigger a seal in the gravel framework. A detailed description of the algorithm defining the depth and thickness of sealing in the gravel framework is given in Chapter xx Sections I and C-3.

FILE STRUCTURE

The SSAM model package employs the linked HEC-6 and SNTEMP models (SSAMDR) to generate the hydraulic and water temperature data required to drive the redd habitat model. The SSAMDR program utilizes formatted sequentially organized input files created by the user. An unformatted binary file is written by SSAMDR containing hydraulic and water temperature data. This file, in addition to the job control and redd data files, drives the sediment intrusion calculations. Output from SSAM is in the form of sequential formatted files.

This section contains input file format information and a brief description of output options.

Input Files

A detailed description of the input file format required by the HEC-6 is given in HEC (1977) Exhibit 6 and an example input file is displayed on pages 25 to 27. A rating curve is required for each of the 15 size fractions transported by HEC-6. Hence, I2, I3 and I4 cards should be included in the HEC-6 input data file. If a size fraction is not in transport in the spawning reach it should be included in L cards but assigned a zero load. The first T card should contain a reasonable approximation of the mean reach water temperature (degrees F) for the first day of simulation and the following days should contain T cards with blank temperature data.

The USERS MANUAL for SNTEMP (Theurer 1984) provides detailed descriptions of the input file formats. For convenient reference to the SNTEMP USER MANUAL Table II-3 provides page numbers for input file formats and example file illustrations.

Table II-3. Page Numbers for SNTEMP Input File Formats and Example File Illustrations (Theurer 1985).

SNTEMP INPUT FILE	PAGE	
	FILE FORMAT	EXAMPLE FILE
1. Job Control	III-76 to 82	III-96
2. Time period	III-83 to 84	III-97
3. Meteorology	III-84 to 85	III-98
4. Skeleton network	III-86	III-100
5. Stream geometry	III-88	III-100 to 111
6. Study file	III-89	III-102
7. Hydrology node	III-90	III-103
8. Hydrology data	III-91	III-103 to 104
9. Shade data (optional)	III-91 to 92	III-104 to 106

In the geometry file the user must identify each cross section used in HEC-6 simulations as a C node to assure accurate calculation of the mean reach water

temperature. The C node descriptions should preceed other node descriptions for the same cross section. Although, stream width is passed, dynamically, from HEC-6 to the heat transport module (TRNSPT), an estimate of the stream width is required for calculation of local solar shading. Hence, the user must input an estimate of the bank-to-bank distance (stream width coefficient) for each cross section in the geometry file. The stream width exponent should be zero. The stream hydrological, meteorological and time period files should contain the same time horizon specifications as used in the HEC-6 hydrological data file.

In addition to the hydraulics binary file created by SSAMDR, the user must provide the job control file and a data set describing the redd environment. All input files use 8 column field widths and, except where indicated, are input as real numbers containing a decimal point.

Job Control File. The job control file is required for execution of the SSAMDR and SSAM programs. It contains some general site information, the simulation time horizon information, output requests and file logical unit number information. As previously mentioned, the time horizon for SSAM simulations may be a subset of the time horizon for SSAMDR simulations. The job control file should be named DRVR.DAT and the format is presented in Table II-4.

Table II-4. Job Control File Format (DRVR.DAT)

RECORD	FIELD	IDENTIFIER	DESCRIPTION
1	1-130	---	Title Line
2	1-130	---	Label Line
3	1-8	NSTA	Total number of stations used in HEC-6 simulations
3	9-16	NDAY	Total number of days in simulation
3	17-24	JDBGN	Julian day beginning simulation
4	1-130	---	Blank line
5	1-130	---	Title line
6	1-130	---	Label line
7	1-8	NDOUT	Time increment (days) for SSAM model output

7	9-16	OPTION	Simulation option
7	17-24	MODE	Output option
7	25-32	SIDOUT	Logical unit number assigned to sequential formatted output file
7	33-40	JSIDOIN	Logical unit number assigned to sequential formatted input file (RDSPCS.DAT)

The input file describing the specific redds for simulation contains information locating each redd within the study reach, the initial particle size distribution within each redd and variable values controlling intragravel flow calculations. The completed input file can be used identically as input for the SSAMDR program and the SSAM program. The redd specification file should be named RDSPCS.DAT and the format is provided in Table II-5.

Table II-5. Redd Specifications Data File Format (RDSPCS.DAT)

RECORD	FIELD	IDENTIFIER	DESCRIPTION
1	1-130	---	Title Line
2	1-130	---	Label Line
3	1-8	NRDXST	Number of upstream cross sections used to identify redd locations
3	9-16	RELEV	Elevation of spawning grounds (ft)
3	17-24	AVGBDPV	Calibration variable for bed load concentration at redd domain boundary
3	25-32	SWSADJ	Multiplicative variable to adjust particle settling velocity for reduced speed in the intragravel environment
3	33-40	UDSTB2	Flag to assign undisturbed zone blocked status at the beginning of simulation (TRUE - Blocked, FALSE - pass through)
4	1-130	---	Blank line
5	1-130	---	Title line
6	1-130	---	Label line
7	1-72	SGG(1-9)	Specific gravity of clay through coarse sand particles
8	1-130	---	Blank line
9	1-130	---	Title line
10	1-130	---	Label line
11	1-64	SGG(10-17)	Specific gravity of very coarse sand through large cobble particles
11	65-72	BSWMIX(1)	Bulk specific weight of substrate material in undisturbed zone immediately after redd construction
12	1-130	---	Blank line
13	1-130	---	Title line
14	1-130	---	Label line

15	1-8	NRDXS	Cross section number, numbered consecutively in reach from upstream, immediately above redd of interest
15	9-16	NBP	Number of break points in cross section
15	17-24	NRDS	Number of redds for analysis immediately below cross section
15	25-32	ISECS	Number of subsections created in cross section
15	33-40	IREID	Flag to indicate that all redds below cross section have identical physical characteristics (IREID = 1) or specific characteristics for each redd follow (IREID ≠ 1)
16	1-130	---	Blank line
17	1-130	---	Title line
18	1-130	---	Label line
19	1-8	DSTL(1)	Distance of 1st Redd site from left end of cross section looking down stream (ft)
19	8-16	DSTUP(1)	Distance of 1st Redd site from down stream cross section (ft)
19	17-24	SSRD(1)	Subsection containing 1st Redd site
19	1-8	DSTL(2)	Distance of 2nd Redd site from left end of cross section looking down stream (ft)
19	8-16	DSTUP(2)	Distance of 2nd Redd site from down stream cross section (ft)
19	17-24	SSRD(2)	Subsection containing 2nd Redd site
19	1-8	DSTL(3)	Distance of 3rd Redd site from left end of cross section looking down stream (ft)
19	8-16	DSTUP(3)	Distance of 3rd Redd site from down stream cross section (ft)
19	17-24	SSRD(3)	Subsection containing 3rd Redd site
20	1-130	---	Blank line
21	1-130	---	Title line
22	1-130	---	Label line
23	1-8	DSTL(4)	Distance of 4th Redd site from left end of cross section looking down stream (ft)
23	8-16	DSTUP(4)	Distance of 4th Redd site from down stream cross section (ft)
23	17-24	SSRD(4)	Subsection containing 4th Redd site
23	25-32	DSTL(5)	Distance of 5th Redd site from left end of cross section looking down stream (ft)
23	33-40	DSTUP(5)	Distance of 5th Redd site from down stream cross section (ft)
23	41-48	SSRD(5)	Subsection containing 5th Redd site
24	1-130	---	Blank line
25	1-130	---	Title line
26	1-130	---	Label line
27	1-50	SSECTRD(I= 1..50)	Definition of subsections by cross section break point
28	1-50	SSECTRD(I=51..100)	Definition of subsections by cross section break point
29	1-130	---	Blank line
30	1-130	---	Title line
31	1-130	---	Label line
32	1-8	ALPHA	Dimensionless variable controlling

			water leakage through redd bottom
32	9-16	CPERM	Dimensionless variable controlling adjustment of hydraulic conductivity in clean and partially filled gravel (percent)
32	17-24	CBADJ	Dimensionless variable controlling the concentration of infiltrating suspended fines at the stream-redd interface
32	25-32	VSADJ	Dimensionless constant controlling the rate of intragravel sediment settling
32	33-40	BSWFNS	Bulk specific weight of fine matrix material (#/ft^3)
32	41-48	BSWGRV	Bulk specific weight of gravel framework (#/ft^3)
32	49-56	FISH	Flag indicating fish species for redd (FISH = 1. - Chinook, FISH = 0. - Steelhead)
32	57- 64	DPSEAL	Dimensionless variable multiplied by D_{90} of the disturbed zone defining the depth of seal development
32	65-72	THSEAL	Thickness of intruding material, of required particle size distribution and as solid mass, required to trigger a seal (feet)
33	1-130	---	Blank line
34	1-130	---	Title line
35	1-130	---	Label line
36	1-72	PCF(K= 1-9,1)	Particle mass fraction finer in undisturbed zone (millimeters)
37	1-80	PCF(K= 10-19,1), BSWMIX(1)	Particle mass fraction finer in undisturbed zone, bulk specific weight of sediment mixture in undisturbed zone
38	1-130	---	Blank line
39	1-130	---	Title line
40	1-130	---	Label line
41	1-72	PCF(K= 1-9,2)	Particle mass fraction finer in disturbed zone
42	1-80	PCF(K= 10-19,2), BSWMIX(2)	Particle mass fraction finer in disturbed zone, bulk specific weight of sediment mixture in egg zone
43	1-130	---	Blank line
44	1-130	---	Title line
45	1-130	---	Label line
46	1-72	PCF(K= 1-9,3)	Particle mass fraction finer in egg zone
47	1-80	PCF(K= 10-19,3), BSWMIX(3)	Particle mass fraction finer in Egg zone, bulk specific weight of sediment mixture in egg zone (#/ft^3)
48	1-130	---	Blank line
49	1-130	---	Title line
50	1-130	---	Label line
51	1-8	EGGD15	Particle size diameter for which 15% of the mass is finer (D_{15}) in the egg zone (millimeters)
51	9-16	EGGD50	Particle size diameter for which 50% of the mass is finer (D_{50}) in the egg zone (millimeters)
51	17-24	EGGD90	Particle size diameter for which 90% of the mass is finer (D_{90}) in the egg

			zone (millimeters)
51	1-130	---	Blank line
51	1-130	---	Title line
51	1-130	---	Label line
51	1-8	DSTD15	Particle size diameter for which 15% of the mass is finer (D_{15}) in the disturbed zone (millimeters)
51	9-16	DSTD50	Particle size diameter for which 50% of the mass is finer (D_{50}) in the disturbed zone (millimeters)
51	17-24	DSTD90	Particle size diameter for which 90% of the mass is finer (D_{90}) in the disturbed zone (millimeters)
51	25-32	VBSFC	Bed stability factor that triggers filling of the pit and removal of the tailspill (suggested value is VBSFC= 0.65)
51	33-40	PSFPIT	Material composition filling pit (PSFPIT= 1- undisturbed zone, 2- disturbed zone, 3- egg zone, 4- active bed material as dynamically calculated by HEC-6)

Repeat records 12 to 28 to describe an additional cross section and records 29 to 51 for each redd site down stream of the cross section.

The river hydraulic and water temperature data file is generated through execution of SSAMDR and forms the third input data file required for SSAM execution. This file is a direct access, unformatted, binary file having a record length of 1840 words (VAX-VMS system). Each record contains all the information for a day of model simulation. Each record number after the first year of data represents the julian day + n*365. Where n is the number of complete years previously simulated. The file is named SSAMIN.BIN and the format is presented in Table II-6.

Table II-6. Hydraulic and Water Temperature Output Data File Generated Through Execution of the SSAMDR Program and Used as Input by SSAM (SSAMIN.BIN)

WORD POSITION IN RECORD	IDENTIFIER	DESCRIPTION
1	JDAY	Julian day for first year of simulation and julian day + n*365 for n completed years of simulation
2	----	Reserved for future use
3	NRDS	Number of redds in cross section
4	QJDXS	Flow rate through cross section (ft^3/s)
5	----	Reserved for future use

* words 3 to 5 are repeated for each cross section containing redds for up to 8 cross sections *

6	SUQ	Unit water flow rate in subsection ($ft^3/s/ft$)
7	SV	Average water flow velocity in subsection (ft/s)
8	RHYD	Hydraulic radius within subsection (feet)
9	TRDXS	Water temperature in cross section (degrees C)
10	SQ	Water flow rate in subsection (ft^3/s)
11	DSTRD	Distance of downstream edge of redd site from downstream cross section (feet)
12	RLDXSQ	Reach length (feet)
13	SDPTH	Water depth in subsection at upstream cross section (feet)
14	DPTHDN	Water depth in subsection at upstream cross section (feet)
15	BSFRD	Bed stability factor at redd site
16	ASELX	Average water energy slope at upstream cross section
17	SUMUQ2	Sum of the square of the unit water discharges at the upstream cross section $(ft^3/s/ft)^2$
18	----	reserved for future use
19	TPDSEDL(1)	Unit clay load (tpd/ft)
20	TSL	Total unit silt load (tpd/ft)
21	TSDN	Total unit sand and larger load (tpd/ft)
22-35	TPDSEDL(2-15)	Unit sediment load silt-very coarse gravel (tpd/ft)
36-50	BDFC(1-15)	Mass fraction finer of active bed layer at redd site

* Words 6 to 50 are repeated for each redd in simulation for up to 5 redds per cross section *

Output Files

Users are referred to model documentation for the HEC-6 (HEC 1977, pp. 21-38), SNTEMP (Theurer et al. 1984, pp. III-72 to III-75) and SIDO (Alonso et al. 1988, pp. III-25 to III-32) for a detailed description of the formatted output options available from these models.

EXAMPLE MODEL EXECUTION

Execution of SSAM is carried out in several steps. The first step is to run SNTEMP which prepares the meteorological and hydrological data for the heat transport calculations. The time horizon for these calculations should be identical to the time horizon of the data driver simulations (i.e. the HEC-6

and heat transport simulations). It is preferable and convenient to prepare a long simulation covering all conceivable time periods of interest. Thus, this period of simulation, or portions thereof, can be drawn upon in simulations of the redd habitat.

Simulation options for the SNTEMP program are selected through editing the job control file for SNTEMP (Theurer et al. 1985). Then the job control program is executed.

```
JBCNUD
```

A prompt for the name of the job control data file is followed by a prompt to begin interactive editing of the job control data. The interactive editing of the job control data should be declined.

Once the user has developed all of the input data files required for execution of the SNTEMP water temperature model the following programs may be executed in series.

```
STRGEM
HYDROL
METROL
REGTWO
```

Upon successful execution of these 5 programs the HEC-6 input data file should be assigned to the file name "INFILE". Then the user should execute the program to generate the hydraulic and water temperature data.

```
SSAMDR
```

Upon completion of the SSAMDR program the user may execute the water temperature verification statistics program, VSTATS. The program SSAMDR builds the file SSAMIN.BIN. Using this binary file and the formatted direct access files DRVR.DAT and RDSPCS.DAT the redd habitat simulation program may

SOFTWARE SUPPORT DOCUMENTATION

INTRODUCTION

Software descriptions are available for the SIDO program (Alonso, 1988) and limited software support documentation is available for the HEC-6 (HEC 1977) and SNTEMP (Theurer et al. 1984) models. The following section describes the software developed to adapt the three model packages to simulate sediment intrusion into spawning gravels. The modules developed to adapt the HEC-6, SNTEMP and SIDO programs control the operation of the programs as well as perform supplementary manipulations of the data. The linked HEC-6 and SNTEMP models are termed the SSAMDR program. The modified SIDO program is termed the SSAM model.

SOFTWARE STRUCTURE

Figures III-1 and III-2 display the modular organization and input and output file structure of the SSAMDR and SSAM programs. The modules required to adapt the original programs are shown, however, the modular structure of the original transport programs (bold boxes) is not displayed.

DESCRIPTION OF MODULES

HEC-6/SNTEMP Program Linkage

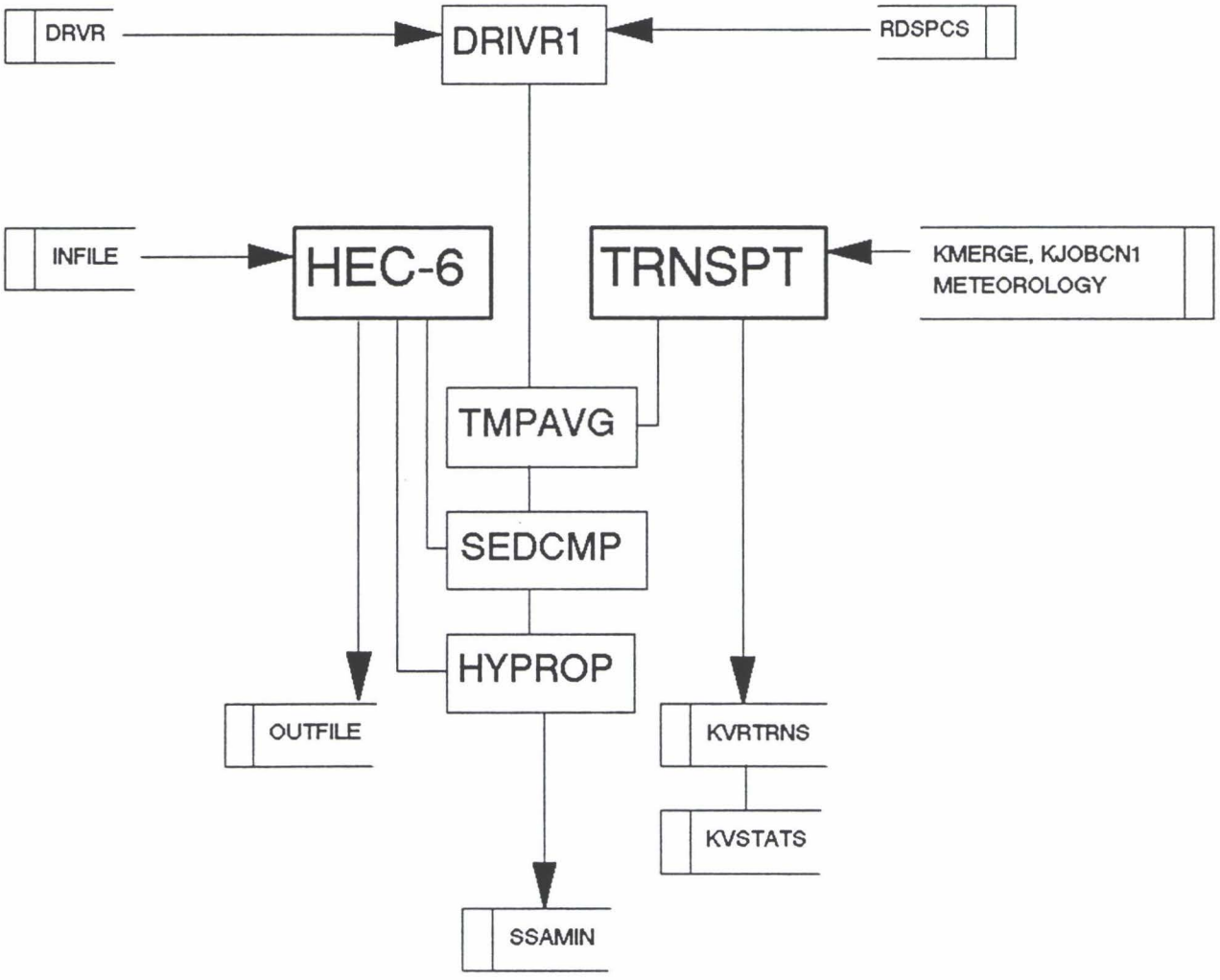


Figure III-1. Organizational chart of SSAMDR program

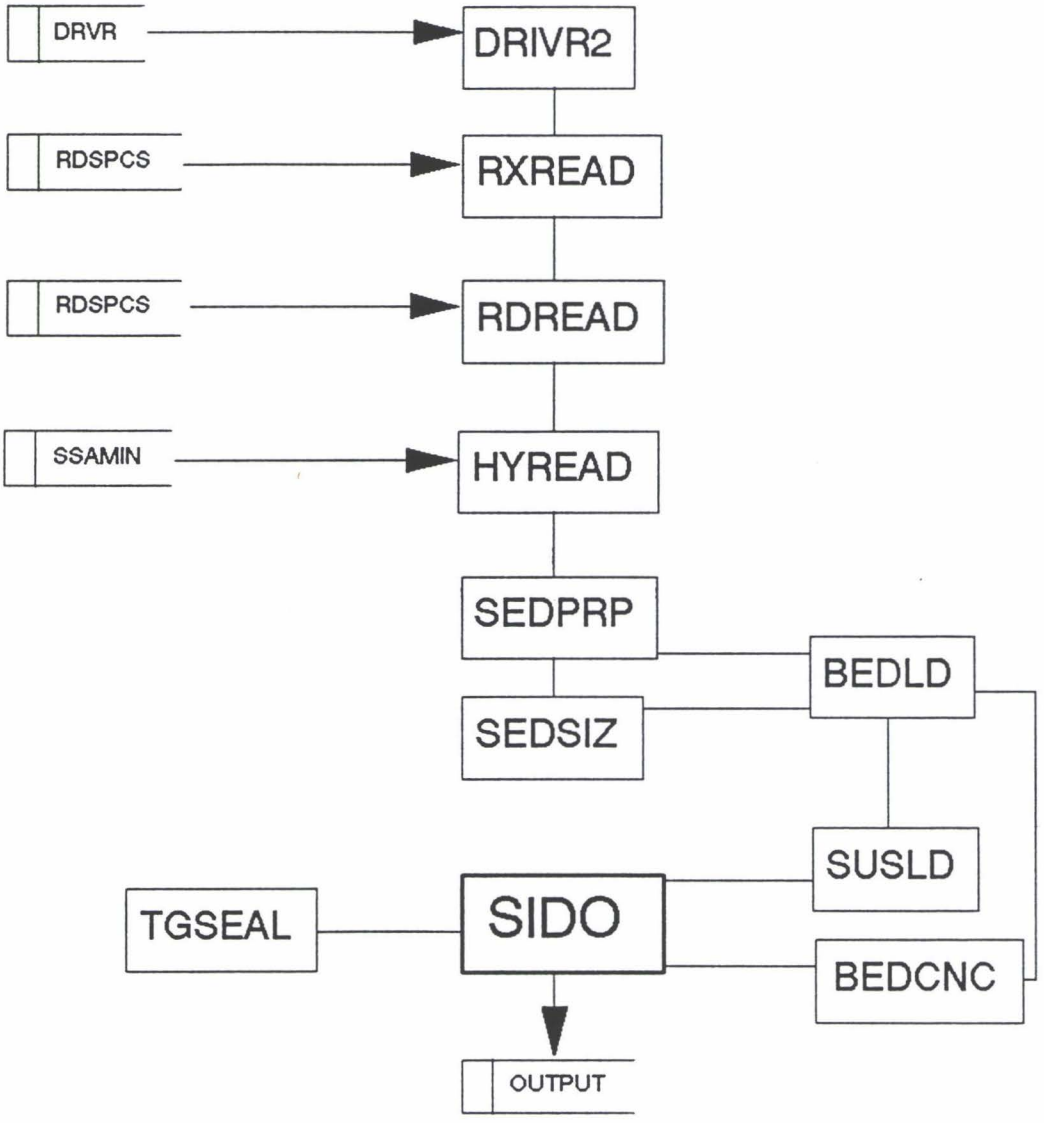


Figure III-2. Organizational chart of SSAM program

Module - DRIVR1

PURPOSE:

This module reads the job control and redd specification geometry data and supervises the execution of the sediment and heat transport programs. The module supervises data processing and construction of the hydraulic data file (SSAMIN.BIN) used to drive the redd habitat program.

METHODS:

1. Open binary files RDSPCS.BIN and SSAMIN.BIN and formatted input files DRVR.DAT and RDSPCS.DAT
2. Read job control and geometry data identifying redds for simulation within the river reach.
3. Prepare hydraulic geometry data for input to SNTEMP model.
4. Increments counter controlling the length of program execution.
5. Stops program execution

CALL FORM: Not Used

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY: None

CALLING MODULE: None

SUBROUTINES CALLED: HEC6, TRNSPT, TMPAVG, SEDCMP

FUNCTIONS CALLED: None

Module - HYPROP

PURPOSE:

This module computes hydraulic properties of a channel cross section.

METHOD:

1. Divides cross section geometry passed by HEC-6 into subsections defined by the user input file RDSPCS.DAT. Compute area, perimeter, conveyance, mean velocity, etc. of individual cross sections.
2. Compute average water depth of subsection at down stream cross section.
3. Pass control back to HEC-6.

CALL FORM: HYPROP

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY: None

CALLING MODULE: BWMOD4

SUBROUTINES CALLED: None

FUNCTIONS CALLED: None

Module - SEDCMP

PURPOSE:

This module assimilates all the data required for driving the redd habitat model and writes the input file SSAMIN.DAT for redd habitat simulations.

METHOD:

1. Read sediment transport and bed gradation data at upstream and downstream cross sections.
2. Interpolate sediment load and bed gradation between cross sections to determine particle size distribution of active layer and sediment transport at a redd site.
3. Write SSAMIN.BIN data file.
4. Pass control back to DRIVR1

CALL FORM: SEDCMP

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY: None

CALLING MODULE: DRIVR1

SUBROUTINES CALLED: None

FUNCTIONS CALLED: None

Module - TMPAVG

PURPOSE:

This module calculates the volumetrically weighted mean water temperature for the river reach.

METHODS

1. Read the river reach hydraulic geometry calculated by HEC-6 and the cross section water temperature data calculated by the TRNSPT module.
2. Calculate the mean, volumetrically weighted, water temperature for the reach.

3. Pass control back to DRIVR1

CALL FORM: TMPAVG

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY: None

CALLING MODULE: DRIVR1

SUBROUTINES CALLED: None

FUNCTIONS CALLED: None

DICTIONARY OF GLOBAL FORTRAN NAMES - **SSAMDR**

ASELX	HYPHEC
BSFDS	SED1
BSFUS	SED1
DPTHDN	HYPSED
EFDDN	HYPHEC
EFDUP	HYPHEC
ELVSCL	DRVR
ISECSX	HYPSED
JDAY	DRVR
JDBGN	DRVR
JDEND	DRVR
JPASS	DRVR
LRDXCNT	DRVR
NDAY	DRVR
NNXS	HYPHEC
NRDXS	DRVR
NRDXST	DRVR
NSTA	DRVR
QJDXS	HYPHEC
RLDX	HYPHEC
SCONV	HYPSED
SDPTH	HYPSED
SQ	HYPSED
SRHY	HYPSED
SUQ	HYPSED
SV	HYPSED
TAREA	HYPSED
TAVG	DRVR
TCONV	HYPSED
TDEPTH	HYPSED
TPER	HYPSED
TRDXS	DRVR
TRHY	HYPSED
TTOP	HYPSED
TW	HYPSED
WSDNST	HYPHEC
WSJDX	HYPHEC
WSUPST	HYPHEC
XNXSECT	HYPHEC
XX	HYPHEC
XXDN	HYPHEC
YY	HYPHEC
YYDN	HYPHEC

Common Block Name: DRVR
Purpose: Transfer variables controlling run execution
Used in Modules: BWMOD4, DRIVR1, HYPROP, NETWRK, SEDCMP, TMPAVG, TRNSPT

ELVSCL Units: feet Dim: scalar;
Desc: Base elevation of spawning reach
Init: DRIVR1

JDAY Units: day Dim: scalar ;
Desc: Counter to determine end of program execution in main driver module
Init: DRIVR1

JDBGN Units: julian day Dim: scalar ;
Desc: User input variable fixing julian day of beginning of program execution
Init: DRIVR1

JDEND Units: day Dim: scalar ;
Desc: Flag to signal end of program execution. JDEND= JDBGN + NDAY
Init: DRIVR1

JPASS Units: day Dim: scalar;
Desc: Counter controlling length of program execution
Init: DRIVR1

LRDXCNT Units: none Dim: scalar ;
Desc: Cross section counter, down stream to upstream, triggers exit to HYPROP for subsection hydraulic geometry calculations
Init: BWMOD4

NDAY Units: day Dim: scalar ;
Desc: User input variable defining the length of program simulation
Init: DRIVR1

NRDXS Units: none Dim: scalar ;
Desc: Sequential cross section number, counting from up stream to down stream
Init: DRIVR1

NRDXST Units: none Dim: scalar;
Desc: Total number of cross sections associated with redd simulation or having user defined subsections
Init: DRIVR1

NSTA Units: none Dim: scalar ;
Desc: Total number of cross sections used in HEC-6 simulations
Init: DRIVR1

TAVG Units: degrees F Dim: scalar ;
Desc: Mean water temperature in reach
Init: TMPAVG

JPASS Units: day Dim: scalar;
Desc: Counter controlling length of program execution
Init: DRIVR1

TRDXS Units: degrees F Dim: scalar ;
Desc: Mean water temperature at cross section
Init: DRIVR1

Common Block Name: HYPHEC
Purpose: Transfer variables used to compute hydraulic geometry of cross sections
Used in Modules: BWMOD4, DRIVR1, HYPROP, SEDCMP, SRMOD5

ASELX Units: ft/ft Dim: 8 ; s1: cross section
Desc: Mean energy slope
Init: BWMOD4

EFDDN Units: feet Dim: 40 ; s1: water depth
Desc: Mean water depth at down stream cross section
Init: BWMOD4

EFDUP Units: feet Dim: 40 ; s1: water depth
Desc: Mean water depth at up stream cross section
Init: BWMOD4

NNXS Units: none Dim: scalar ;
Desc: Variable that counts the number of cross sections
Init: BWMOD4

QJDXS Units: ft^3/s Dim: 8 ; s1: flow rate
Desc: Mean flow rate at cross section
Init: BWMOD4

RLDX Units: feet Dim: 8 ; s1: reach length
Desc: Reach length between cross sections
Init: BWMOD4

SUQ Units: $ft^3/s/ft$ Dim: 8,5 ; s1: cross section, s2: subsection
Desc: Unit flow rate in subsection
Init: HYPROP

WSDNST Units: feet Dim: 8 ; s1: water surface elevation
Desc: Water surface elevation at down stream cross section
Init: BWMOD4

WSJDX Units: feet Dim: 8 ; s1: water surface elevation
Desc: Water surface elevation at up stream cross section
Init: BWMOD4

XNXSECT Units: $ft^{1/6}$ Dim: scalar
Desc: Manning n
Init: BWMOD4

XX Units: feet Dim: 100 ; s1: distance
Desc: Up stream cross section station distance
Init: BWMOD4

XXDN Units: feet Dim: 100 ; s1: distance
Desc: Down stream cross section station distance
Init: BWMOD4

YY Units: feet Dim: 100 ; s1: elevation
Desc: Up stream cross section station elevation
Init: BWMOD4

YYDN Units: feet Dim: 100 ; s1: elevation
Desc: Down stream cross section station elevation

Common Block Name: HYPSED
Purpose: Transfer variables used calculation of subsection hydraulic geometry (HYPROP) to the module (SEDCMP) which writes the hydraulic data file (SSAMIN.BIN)
Used in Modules: DRIVR1, HYPROP, SEDCMP, SRMOD5

DPTHDN Units: feet Dim: 8,5 ; s1: cross section index, s2; subsection index
Desc: Water depth at down stream cross section from redd under simulation. The depth is averaged over 10 feet at a lateral position approximating the position of the redd.
Init: HYPROP

ISECSX Units: none Dim: 8 ; s1: subsection index
Desc: Array contains the number of user defined subsections contained in each cross section under consideration
Init: HYPROP

SCONV Units: ft^3/s Dim: 8,5 ; s1: cross section index, s2: subsection index
Desc: Conveyance of subsection
Init: HYPROP

SDPTH Units: feet Dim: 8,5 ; s1: cross section index, s2: subsection index
Desc: Mean subsection depth
Init: HYPROP

SQ Units: ft^3/s Dim: 8,5 ; s1: cross section index, s2; subsection index
Desc: Flow rate through subsection
Init: HYPROP

SRHY Units: feet Dim: 8,5; s1: cross section index., s2: subsection index.
Desc: Hydraulic radius of subsection
Init: HYPROP

SUQ Units: $ft^3/s/ft$ Dim: 8,5 ; s1: cross section index., s2: subsection index.
Desc: Unit flow rate of subsection
Init: HYPROP

SV Units: ft/s Dim: 8,5 ; s1: cross section index., s2: subsection index.
Desc: Mean velocity of subsection
Init: HYPROP

TAREA Units: ft^2 Dim: 8 ; s1: cross section index.
Desc: Sum of subsection areas at cross section
Init: HYPROP

TCONV Units: ft^3/s Dim: 8 ; s1: cross section index.
Desc: Sum of subsection conveyances for cross section
Init: HYPROP

TDEPTH Units: feet Dim: 8 ; s1: cross section index.
Desc: Maximum depth of cross section
Init: HYPROP

TPER Units: feet Dim: 8 ; s1: cross section index.,
Desc: Wetted perimeter of cross section
Init: HYPROP

TTOP Units: feet Dim: 8 ; s1: cross section index.
Desc: Free surface width of cross section
Init: HYPROP

TW Units: feet Dim: 5; s1: sub section index.
Desc: Free surface width of subsection
Init: HYPROP

Common Block Name: SED1
Purpose: Transfer bed stability factor from HEC-6 to SEDCMP module
Used in Modules: SEDCMP, SRMOD5

BSFUS Units: none Dim: 40 ; s1: cross section index.
Desc: Bed stability factor at up stream cross section
Init: SRMOD5

BSFDS Units: none Dim: 40 s1: cross section index.
Desc: Bed stability factor at down stream cross section
Init: SRMOD5

Module - BEDCNC

PURPOSE:

Calculate the particle size that will intrude under the Einstein mode and calculate the concentration of these particles at the redd domain boundary.

METHOD:

1. If the D_{50} of the disturbed zone is greater than 14 times the bed load particle size then the concentration of the particle size at the boundary of the redd is calculated.

2. If the bed load particle size is greater than the D_{50} of the disturbed zone then the particle is allowed to pass over the redd.

CALL FORM: BEDCNC (TBLPPS, TAU0)

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY:

TAU0: shear stress (#/ft^2)
TBLPPS: total bed load rate (#/s/ft)

CALLING MODULE: BEDLD

SUBROUTINES CALLED: None

FUNCTIONS CALLED: None

Module - BEDLD

PURPOSE:

Allocate total sediment load into bed and suspended load regions. Weight load laterally in the cross section. Prepare bed load data for daily calculation of particle size statistics.

METHOD:

1. Estimate water depth at redd location through longitudinal interpolation.

2. Calculate shear velocity at redd using formula for rough boundaries (Rouse, 1946, P. 195).

3. If shear velocity is greater than 0.8 times particle settling velocity then particle is assigned to suspended load.

4. Calculate suspended load for each particle size fraction in suspension.

5. Weight bed load laterally in the cross section based on the square of the unit subsection flow rate.

6. Calculate bed load rates for each particle size fraction present in bed load.

7. Calculate percent finer for bed load particle sizes.

8. Call modules to calculate bed load particle size statistics and sediment concentration at stream substrate surface.

9. Return control to DRIVR2

CALL FORM: BEDLD

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY:

TAU0: shear stress (#/ft^2)
TBLPPS: total bed load rate (#/s/ft)
TSLDPPS: total suspended sediment load (#/s/ft)

CALLING MODULE: DRIVR2

SUBROUTINES CALLED: SEDSIZ, BEDCNC, SUSLD

FUNCTIONS CALLED: None

Module - DRIVR2

PURPOSE:

To read job control data and supervise the temporal simulation of up to 40 redds in series.

METHOD:

1. Read job control data and set initial conditions for redd pit and tailspill.

2. Supervise reading of redd initial conditions, reading of daily hydraulic input data and calculation of boundary conditions for redd habitat simulation.

CALL FORM: None

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY:

JSIDOIN:	logical unit number assigned by user to the input file RDSPCS.DAT
IRDID:	flag to indicate that all redds at the current cross section have identical physical attributes and intragravel flow parameter values.
NRDS:	number of redds below current cross section
JRDD:	counter to identify redds within cross section
JDAY:	julian day or sequence day
DOUT:	real number value for number of days between output request
IDATE:	number of days since beginning of simulation
DOAVG:	average dissolved oxygen concentration in egg zone at end of day (mg/L)
PF085:	particle mass percent finer than 0.85 mm averaged over the redd zone at end of day
PF950:	particle mass percent finer than 9.50 mm averaged over the redd zone at end of day

CALLING MODULE: None

SUBROUTINES CALLED:

RXREAD, RDREAD, HYREAD, SFPROP, INTERP

FUNCTIONS CALLED: None

Module - HYREAD

PURPOSE:

Read daily hydraulic data from binary file SSAMIN.BIN.

METHOD:

1. Calculate position of cross section and redd information in input file SSAMIN.BIN.

2. Data is read and passed to modules through common blocks.

3. Returns control to DRIVR2

CALL FORM: HYREAD(JDAY, JRDD, IRDXS)

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY:

JSIDOIN:	logical unit number assigned by user to the input file RDSPCS.DAT
IRDID:	flag to indicate that all redds at the current cross section have identical physical attributes and intragravel flow parameter values.
NRDS:	number of redds below current cross section

CALLING MODULE: DRIVR2

SUBROUTINES CALLED: None

FUNCTIONS CALLED: None

Module - RDREAD

PURPOSE:

Read initial conditions and simulation variables specific to each redd being simulated.

METHOD:

1. Reads redd initial conditions and simulation variables for first redd in cross section. Assigns identical initial condition and simulation variables to additional redds in different portions of cross section if IRDID = 1.

2. Initializes variables for particular fish species.

3. Returns control to DRIVR2

CALL FORM: RDREAD(JSIDOIN, JRDD, IRDID)

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY:

JSIDOIN: logical unit number assigned by user to the input file RDSPCS.DAT
IRDID: flag to indicate that all redds at the current cross section have identical physical attributes and intragravel flow parameter values.
NRDS: number of redds below current cross section

CALLING MODULE: DRIVR2

SUBROUTINES CALLED: None

FUNCTIONS CALLED: None

Module - RXREAD

PURPOSE:

Read information to control simulation of redds in cross section.

METHOD:

1. Read RDSPCS.DAT redd specification data.

2. Skip cross section geometry information contained in RDSPCS.DAT which is used in SSAMDR program.

CALL FORM: RXREAD(JSIDOIN, IRDID, NRDS)

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY:

JSIDOIN: logical unit number assigned by user to the input file RDSPCS.DAT
IRDID: flag to indicate that all redds at the current cross section have identical physical attributes and intragravel flow parameter values.
NRDS: number of redds below current cross section

CALLING MODULE: DRIVR2

SUBROUTINES CALLED: None

FUNCTIONS CALLED: None

Module - SEDPRP

PURPOSE:

Prepare sediment load data calculated in program SSAMDR for use in SSAM.

METHOD:

1. Calculate bed gradation sediment particle size statistics for redd site.

2. Initiate calculation of bed and suspended load concentration for boundary conditions on redd domain.

3. Return control to DRIVR2.

CALL FORM: SEDPRP

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY:

BDPF:	array containing active bed material mass percent finer data
DIABDG:	array containing particle diameter limits of size classes in bed (millimeters)
DZ:	array containing particle size statistics (millimeters)

CALLING MODULE: DRIVR2

SUBROUTINES CALLED: SEDSIZ, BEDLD

FUNCTIONS CALLED: None

Module - SEDSIZ

PURPOSE:

Calculate particle size statistics from input particle percent finer data.

REFERENCE:

Stevens, H. H. and D. W. Hubbell. 1986. Computer programs for computing particle-size statistics of fluvial sediments. U. S. Geological Survey, Water-Resources Investigations Report 86-4141, Denver Colorado.

Module - SUSLD

PURPOSE:

Calculate suspended load concentration at stream substrate surface.

METHOD:

1. Convert pounds per second to concentration units.
2. Return control to module BEDLD

CALL FORM: SUSLD (TSLDPPS)

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY:

TSLDPPS: total suspended sediment load (#/s/ft)

CALLING MODULE: BEDLD

SUBROUTINES CALLED: None

FUNCTIONS CALLED: None

Module - TGSEAL

PURPOSE:

This module compares the bed load particle size distribution statistics with the Diplas-Parker criterium for the Beschta sediment intrusion mode. When these conditions are met, a seal is triggered in the gravel framework material.

METHOD:

1. Bed load particle size statistics are compared to the disturbed zone particle size distribution using the Diplas-Parker criterium.

2. If the criterium in 1 is met, the intruding bed load mass for the day is calculated to determine if enough material is available to seal a cell in the finite difference grid.

3. The depth of the seal is calculated.

4. When sufficient material has accumulated a cell is sealed.

5. If the pit has not filled sealing begins near the bottom of the pit and progresses through the seal depth in the disturbed zone.

CALL FORM: TGSEAL (ICCLTG)

PASSED ARGUMENTS NOT LISTED IN GLOBAL DICTIONARY:

ICCLTG: counts number of cells in which a seal has been triggered, and is used to suspend checking for potential seal formation when the redd has been completely sealed

CALLING MODULE: SEDRIV

SUBROUTINES CALLED: None

FUNCTIONS CALLED: None

DICTIONARY OF GLOBAL FORTRAN NAMES - **SSAM**

ABETA	GWBLK3
ALPHA	GWBLK1
ASWS2	SDBLK1
ASWS3	SDBLK1
AVGBDPV	SDBLK1
B	GWBLK2
B50	STBLK1
BDCNC	SDBLK1
BDCNCS	SDBLK1
BDFF	SDBLK1
BDFC	SDBLK4
BDGD16	SDBLK3
BDGD40	SDBLK3
BDGD50	SDBLK3
BDGD60	SDBLK3
BDGD90	SDBLK3
BDLD15	SDBLK4
BDLD50	SDBLK4
BDLD85	SDBLK4
BDLD90	SDBLK4
BDLDFLX	SDBLK1
BDLDSS	SDBLK4
BDRY	GWBLK4
BDRY	GWBLK4
BLOCK	SDBLK2
BLOCK	SDBLK2
BSFRD	SDBLK3
BSWFNS	SDBLK1
BSWGRV	SDBLK1
BSWMIX	SDBLK1
BTCHNK	GWBLK3
BTSTHD	GWBLK3
CBADJ	SDBLK2
CCNT	STBLK2
CE	DOBLK2
CHNOOK	RCNTRL
CK	GWBLK4
CPERM	GWBLK4
D	GWBLK2
DC	DOBLK2
DDS	SDBLK3
DELC	SDBLK2
DELFNS	SDBLK2
DELT	GWBLK3
DEOXYK	DOBLK2
DFILPIT	SDBLK1
DG	GWBLK4
DGS	SDBLK1
DISSIP	GWBLK6
DND	SDBLK1
DOEXP	DOBLK2
DOXC	DOBLK1
DOYSTR	DOBLK1
DPSEAL	GWBLK3
DSTD15	SDBLK4
DSTD50	SDBLK4
DSTD90	SDBLK4

DSTRD	SDBLK3
DUS	SDBLK3
DXCHNK	GWBLK3
DXSTHD	GWBLK3
DYCHNK	GWBLK3
DYSTHD	GWBLK3
EDT	DOBLK2
EOCMPS	DOBLK2
EODPER	DOBLK2
EPS	STBLK2
FILLED	RCNTRL
FKV	SDBLK1
FLGFIL	RCNTRL
FSLD	SDBLK1
H	GWBLK1
HCLOSE	GWBLK6
HRAD	SDBLK3
HT	DOBLK2
ICXD	GWBLK3
ICXU	GWBLK3
IDATFL	SDBLK2
IT	GWBLK6
ITCNT	SDBLK1
ITMAX	GWBLK6
JDAY	RCNTRL
JDEND	RCNTRL
KE	GWBLK5
KE	GWBLK5
KN	GWBLK5
KS	GWBLK5
KW	GWBLK5
LSF	SDBLK1
MODE	RCNTRL
NBEGGS	DOBLK2
NCOL	GWBLK3
NEWBED	RCNTRL
NLAY	GWBLK3
NODEID	GWBLK4
NOTAIL	RCNTRL
NSF	SDBLK1
NSFIN	SDBLK1
NSFIT	SDBLK1
NSFT	SDBLK1
NSTEPS	GWBLK3
NUREDD	RCNTRL
OMEGA	GWBLK6
OPTION	RCNTRL
OPTION	RCNTRL
PCF	SDBLK1
PCFILL	SDBLK1
PCK	SDBLK1
PERM4	GWBLK4
POROS	GWBLK4
PSFPIT	SDBLK4
QD	STBLK2
QX	GWBLK7
QY	GWBLK7
QYSTDY	STBLK2
RADIUS	DOBLK2
RE	GWBLK2
RELEV	DOBLK1
RESA	GWBLK6

RESM	GWBLK6
RLN	SDBLK3
RMCAL	STBLK2
RN	GWBLK2
RS	GWBLK2
RW	GWBLK2
SCREEN	RCNTRL
SDLDSS	SDBLK4
SEALED	SDBLK4
SEDC1	SDBLK2
SEDC2	SDBLK2
SEDC3	SDBLK2
SEDSOC	DOBLK2
SGG	SDBLK1
SIDOIN	RCNTRL
SIDOUT	RCNTRL
SLOAD	SDBLK4
SOCMPS	DOBLK2
SOD	DOBLK2
SODADD	DOBLK2
SODBEG	DOBLK2
SODEND	DOBLK2
SQ	SDBLK3
STAGE	STBLK2
STBD	SDBLK4
STLHD	RCNTRL
STVM	SDBLK3
SUMUQ2	SDBLK3
SUQ	SDBLK3
SV	SDBLK1
SWS	SDBLK1
SWW	SDBLK1
TBD	SDBLK4
TBDLDSS	SDBLK1
TBLDPLF	SDBLK1
TEMP	STBLK2
THICK	DOBLK2
THSEAL	GWBLK3
TLD	SDBLK3
TMPREF	DOBLK2
TOC	DOBLK1
TPDSEDL	SDBLK3
TQD	SDBLK3
UDSTB2	SDBLK1
V	GWBLK1
VBSFC	SDBLK4
VEGGZN	DOBLK2
VELCMS	DOBLK2
VSADJ	SDBLK2
VX	GWBLK7
VY	GWBLK7
W	GWBLK1
WK	SDBLK1
WSS	SDBLK1
X0REDD	GWBLK3
XDEL	GWBLK3
YDEL	GWBLK3
ZETA	SDBLK1

Common Block Name: DOBLK1
Purpose: Transfer variables used in dissolved-oxygen transport calculations
Used in Modules: BLKDAT, CNTOUR, CSOLVR, DODRIV, DOXBED, DRIVR2, EMERGE, GWDRIV, HYREAD, INTERP, REDDOX, TABLE, TOD, VTABLE

DOXC Units: mg/liter Dim: 0:21,0:13,2 ; s1: column no., s2: layer no., s3: time level
Desc: Concentration of dissolved oxygen at cell-centered nodes
Init: DODRIV

DOYSTR Units: mg/liter Dim: scalar ;
Desc: Average concentration of dissolved oxygen in egg zone at beginning of day
Init: INTERP

RELEV Units: feet Dim: scalar ;
Desc: Redd elevation above mean sea level
Init: DRIVR2

TOC Units: mg/liter/day Dim: 20,12 ; s1: column no., s2:layer no.
Desc: Total oxygen consumption in a cell during a day
Init: TOD

Common Block Name: DOBLK2
Purpose: Transfer variables used to compute DO consumption rates
Used in Modules: BLKDAT, TOD, VTABLE

CE Units: mg/cc Dim: 2 ; s1: chinook, s2: steelhead
Desc: Oxygen concentration within egg capsule
Init: BLKDAT

DC Units: cm2/sec Dim: 2 ; s1: chinook, s2: steelhead ;
Desc: Diffusion coefficient of oxygen through egg capsule wall
Init: BLKDAT

DEOXYK Units: none Dim: scalar ;
Desc: Dimensionless deoxygenation constant
Init: BLKDAT

DOEXP Units: none Dim: scalar ;
Desc: Exponent in dissolved-oxygen status correction factor
Init: BLKDAT

EDT Units: none Dim: scalar ;
Desc: Relative development time of eggs
Init: TOD

EOCMPS Units: mg/liter/day Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Actual egg oxygen consumption in a cell under a given water temperature, dissolved oxygen status velocity near eggs, and interstitial water
Init: EOC

EODPER Units: percent Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Current day's egg oxygen demand satisfaction in a cell
Init: EOC

HT Units: days Dim: scalar ;
Desc: Hatching time for eggs
Init: TOD

NBEGGS Units: eggs Dim: 2 ; s1: species (1-chinook, 2-steelhead)
Desc: Hatching time for eggs
Init: TOD

RADIUS Units: centimeters Dim: 2 ; s1: species (1-chinook,2-steelhead)
Desc: Radius of egg
Init: EOC

SEDSOC Units: mg O2/gram Dim: scalar ;
Desc: Factor relating sediment oxygen demand to additional silt and clay mixture accumulating within the substrate during the day
Init: BLKDAT

SOCMPS Units: mg/liter/day Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Sediment oxygen consumption in a cell during a day

Init: SOC

SOD Units: mg/liter/day Dim: 20,12 ; s1: column no.,s2: layer no.
Desc: Sediment oxygen demand in a cell at the beginning of the day
Init: TOD

SODADD Units: mg/liter Dim: 20,12; s1: column no.,s2: layer no.
Desc: Daily increase of sediment oxygen consumption in a cell due to addition of fine sediments
Init: SOC

SODBEG Units: mg/liter Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Sediment oxygen demand in a cell at the beginning of the day
Init: TOD, SOC

SODEND Units: mg/liter Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Sediment oxygen demand in a cell at the end of the day
Init: TOD, SOC

THICK Units: centimeter Dim: 2 ; s1: species (1-chinook, 2-steelhead)
Desc: Egg capsule thickness
Init: EOC

TMPREF Units: Celsius degrees Dim: scalar ;
Desc: Reference temperature used to evaluate sediment oxygen consumption rate
Init: BLKDAT

VEGGZN Units: liters Dim: 2 ; s1: species (1-chinook, 2-steelhead)
Desc: Volume of egg zone
Init: EOC

VELCMS Units: cm/sec Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Magnitude of interstitial water velocity in a cell
Init: TOD

Common Block Name: GWBLK1
Purpose: Transfer variables used to update SOR estimates of hydraulic pressure distribution in redd
Used in Modules: BLKDAT, BOUND, CNVG, GWDRIV, HSOLVR, INITHC, KSET, QCALC, RDREAD, TABLE

ALPHA Units: none Dim: scalar
Desc: Dimensionless factor controlling water leakage through redd bottom
Init: RDREAD

H Units: feet Dim: 0:21,0:13 ; s1: column no., s2: layer no.
Desc: Pressure head in a cell at the start of time step
Init: BLKDAT

V Units: feet Dim: 0:21,0:13 ; s1: column no., s2: layer no.
Desc: Next to last SOR estimate of pressure in a cell
Init: BLKDAT

W Units: feet Dim: 0:21,0:13 ; s1: column no., s2: layer no.
Desc: Latest SOR estimate of pressure in a cell and, upon completion of time step, final pressure
Init: BLKDAT

Common Block Name: GWBLK2
Purpose: Transfer variables used in SOR updating of hydraulic pressure distribution in redd
Used in Modules: BLKDAT, CNVG, HSOLVR, KSET, QCALC

B Units: 1/ft Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Array storing denominators for SOR sweeps
Init: KSET

D Units: none Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Array storing denominators for SOR sweeps
Init: HSOLVR

RE Units: min/ft^2 Dim: scalar ;
Desc: Coefficient used in SOR update of pressure heads
Init: KSET

RN Units: min/ft^2 Dim: scalar ;
Desc: Coefficient used in SOR update of pressure heads
Init: KSET

RS Units: min/ft^2 Dim: scalar ;
Desc: Coefficient used in SOR update of pressure heads
Init: KSET

RW Units: min/ft^2 Dim: scalar ;
Desc: Coefficient used in SOR update of pressure heads
Init: KSET

Common Block Name: GWBLK3
Purpose: Transfer variables used to set up geometric configuration of redd
Used in Modules: ADTFNS, BLKDAT, BOUND, CHKBKG, CNVG, CNTOUR, CSOLVR, DODRIV, DOXBED, EMERGE, GWDRIV, HSOLVR, INITHC, INTKPB, KSET, MAPBKG, QCALC, RDDSED, RDDWAT, RDREAD, READER, RSTKP4, SEDBED, STDRIV, STLNPT, TABLE, TOD, UPDATE, VTABLE

ABETA Units: degrees Dim: scalar ;
Desc: Initial angle between stream bed surface and upstream face of tailspill
Init: BLKDAT
This parameter takes the value assigned to either BTCHNK or BTSTHD depending on the selected species

BTCHNK Units: degrees Dim: scalar ;
Desc: Tailspill angle in a chinook redd
Init: BLKDAT

BTSTHD Units: degrees Dim: scalar ;
Desc: Tailspill angle in a steelhead redd
Init: BLKDAT

DELT Units: minutes Dim: scalar ;
Desc: Length of time step for transient transport calculations
Init: QCALC

DPSEAL Units: feet Dim: scalar ;
Desc: Multiplies D_{90} of gravel matrix to locate depth of seal development
Init: RDREAD

DXCHNK Units: feet Dim: scalar ;
Desc: Width of cells in chinook redds
Init: BLKDAT

DXSTHD Units: feet Dim: scalar ;
Desc: Width of cells in steelhead redds
Init: BLKDAT

DYCHNK Units: feet Dim: scalar ;
Desc: Height of cells in chinook redds
Init: BLKDAT

DYSTHD Units: feet Dim: scalar ;
Desc: Height of cells in steelhead redds
Init: BLKDAT

ICXD Units: none Dim: scalar ;
Desc: ID number of cross section downstream of redd
Init: not used in SSAM

ICXU Units: none Dim: scalar ;
Desc: ID number of cross section upstream of redd
Init: not used in SSAM

NCOL Units: columns Dim: scalar ;
Desc: Number of columns in finite-difference grid
Init: BLKDAT

NLAY Units: layers Dim: scalar ;

Desc: Number of layers in finite-difference grid
Init: BLKDAT

NSTEPS Units: Steps Dim: scalar;
Desc: Number of time steps per day for transient transport calculations
Init: QCALC

THSEAL Units: feet Dim: scalar;
Desc: Thickness of solid sediment mass required to trigger seal
Init: RDREAD

XOREDD Units: feet Dim: scalar ;
Desc: Distance from downstream boundary of redd domain to channel outlet
Init: not used in SSAM

XDEL Units: feet Dim: scalar ;
Desc: Width of finite-difference cells
Init: RDREAD

YDEL Units: feet Dim: scalar ;
Desc: Height of finite-difference cells
Init: RDREAD

Common Block Name: GWBLK4
Purpose: Transfer variables used to characterize hydraulic properties of redd cells
Used in Modules: ADTFNS, BLKDAT, BOUND, CHKBKG, CNVG, DODRIV, EMERGE, HSOLVR, INITHC, INTKPB, KSET, QCALC, RDREAD, RSTKP4, SEDRIV, SFPROP, TABLE, TGSEAL, TOD, UPDATE, VTABLE

BDRY Units: none Dim: 0:21,0:13 ; s1: column no., s2: layer no.
Desc: Array used to identify flow type of cells
Init: INITHC, BOUND

CK Units: ft/min Dim: 0:21,0:13 ; s1: column no., s2: layer no.
Desc: Cell-centered hydraulic conductivity
Init: BLKDAT

CPERM Units: none Dim: scalar ;
Desc: Dimensionless factor controlling exponential adjustment of hydraulic conductivity in disturbed zone
Init: RDREAD

DG Units: millimeters Dim: 20,12 ; s1: column no., s2: layer number
Desc: Effective diameter of framework material stored in each substrate cell immediately after redd construction
Init: INTKPB, RSTKP4

NODEID Units: none Dim: 0:21,1:13 ; s1: column no., s2: layer no.
Desc: Array used to assign cells to different redd zones
Init: BLKDAT

PERM4 Units: none Dim: scalar ;
Desc: Auxiliary coefficient used to set up initial conductivity of void zone
Init: BLKDAT
Used in module INTKPB

POROS Units: none Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Array that holds porosity of redd cells
Init: INTKPB,RSTKP4

Common Block Name: GWBLK5
Purpose: Transfer variables used to define hydraulic conductivity at interfaces of redd cells
Used in Modules: BLKDAT, CNVG, HSOLVR, KSET, QCALC

KE Units: ft/min Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Conductivity on east face of cell
Init: KSET

KN Units: ft/min Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Conductivity on north face of cell
Init: KSET

KS Units: ft/min Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Conductivity on south face of cell
Init: KSET

KW Units: ft/min Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Conductivity on west face of cell
Init: KSET

Common Block Name: GWBLK6
Purpose: Transfer variables used to control intragravel flow calculations
Used in Modules: BLKDAT, CNVG, GWDRIV, HSOLVR, KSET, QCALC

DISSIP Units: none Dim: scalar ;
Desc: Dimensionless coefficient for controlling numerical dispersion in transient transport calculations
Init: BLKDAT

HCLOSE Units: ft^2/min Dim: scalar ;
Desc: Criterion for convergence in the SOR procedure
Init: BLKDAT

IT Units: none Dim: scalar ;
Desc: Iteration number in the SOR procedure for pressure update
Init: GWDRIV

ITMAX Units: iterations Dim: scalar ;
Desc: Maximum number of iterations in pressure calculations
Init: BLKDAT

OMEGA Units: none Dim: scalar ;
Desc: Over relaxation coefficient in the SOR procedure for pressure update
Init: BLKDAT

RESA Units: ft^2/min Dim: scalar ;
Desc: Average over all cells of mass balance residuals
Init: CNVG

RESM Units: ft^2/min Dim: scalar ;
Desc: Maximum over all cells of mass balance residuals
Init: CNVG

Common Block Name: GWBLK7
Purpose: Transfer variables used to describe intragravel fluxes
Used in Modules: BLKDAT, CHKBKG, CNVG, CSOLVR, DODRIV, GWDRIV, HSOLVR, KSET, QCALC, SEDRIV, STLNPT, TABLE, TOD

QX Units: ft/minute Dim: 21,13 ; s1: column no., s2: layer no.
Desc: X component of Darcy flux field at centered nodes
Init: QCALC

QY Units: ft/minute Dim: 21,13 ; s1: column no., s2: layer no.
Desc: Y component of Darcy flux field at centered nodes
Init: QCALC

VX Units: ft/minute Dim: 20,12 ; s1: column no., s2: layer no.
Desc: X component of interstitial velocity field at centered nodes
Init: QCALC

VY Units: ft/minute Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Y component of interstitial velocity field at centered nodes
Init: QCALC

Common Block Name: RCNTRL
Purpose: Transfer variables used to control change actions, to select simulation and output options, and for assignment of data files
Used in Modules: BCKWAT, BEDMOV, BOUND, CHKBKG, CNVG, CONTRL, CSOLVR, DOXBED, DRIVR2, EMERGE, GWDRIV, INITHC, INTERP, INTKPB, KSET, MAPBKG, QCALC, RDDSED, RDDWAT, RDREAD, READER, REDDOX, RSTKP4, SEDRIV, SFPROP, TABLE, TABLE1, TABLE2, TGSEAL, TOD, UPDATE, VTABLE

CHNOOK Units: none Dim: scalar ;
Desc: Logical variable which is set to .TRUE. when a chinook salmon redd is simulated
Init: RDREAD

FILLED Units: none Dim: scalar ;
Desc: Logical variable set to .TRUE. in module BEDMOV to signal the filling of the void zone as the result of bed load movement
Init: Initially set to .FALSE. by the DRIVR2 module

MODE Units: none Dim: scalar ;
Desc: Integer variable used to specify output selection
Init: DRIVR2

NEWBED Units: none Dim: scalar ;
Desc: Logical variable set to .TRUE. in module STDRIV to indicate the occurrence of a extreme stream flow event resulting in the obliteration of the redd
Init: Initially set to .FALSE. by the DRIVR2 module

NOTAIL Units: none Dim: scalar ;
Desc: Logical variable set to .TRUE. in module BEDMOV to signal removal of tailspill
Init: Initially set to .FALSE. by the DRIVR2 module

NUREDD Units: none Dim: scalar ;
Desc: Logical variable set to .TRUE. to signal the start of a redd simulation. This variable is reset to .FALSE. in module INTERP at the end of the first simulated day period
Init: DRIVR2

OPTION Units: none Dim: scalar ;
Desc: Integer variable used to specify routing option
Init: DRIVR2

SIDOIN Units: none Dim: scalar ;
Desc: Logical name of sequential formatted input file
Init: DRIVR2

SIDOUT Units: none Dim: scalar ;
Desc: Logical name of sequential formatted output file
Init: DRIVR2

STLHD Units: none Dim: scalar ;
Desc: Logical flag which is set to .TRUE. when a steelhead salmon redd is simulated
Init: DRIVR2

Common Block Name: SDBLK1
Purpose: Variables used to characterize physical properties of water, sediment load, and substrate material
Used in Modules: ADTFNS, BEDCNC, BEDLD, BLKDAT, BOUND, CHKBKG, DRVR2, EMERGE, GWDRIV, HYREAD, INITHC, INTERP, INTKPB, RDREAD, RSTKP4, SEDBED, SEDPRP, SEDRIV, SFPROP, TABLE, TGSEAL, TOD, UPDATE, VTABLE

ASWS2 Units: ft/min Dim: scalar ;
Desc: Mean weighted settling velocity of silt particles
Init: SEDRIV

ASWS3 Units: ft/min Dim: scalar ;
Desc: Mean weighted settling velocity of silt particles
Init: SEDRIV

AVGBDPV Units: feet Dim: scalar
Desc: Variable representing the range of motion of a bed load particle
Init: DRIVR2

BDCNC Units: dimensionless Dim: 15 ; s1: fraction index
Desc: Concentration of bed load fractions
Init: BDCNC

BDFF Units: decimal Dim: 18 ; s1: size fraction
Desc: Size distribution of active bed material as simulated by HEC-6
Init: SEDPRP

BDLDFLX Units: #/ft Dim: scalar
Desc: Cumulative flux of bed load into redd during one day
Init: CSOLVR

BSWFNS Units: lbs/ft^3 Dim: scalar ;
Desc: Bulk specific weight of infiltrating fine sediment matrix
Init: RDREAD

BSWGRV Units: lbs/ft^3 Dim: scalar ;
Desc: Bulk specific weight of coarse framework material
Init: RDREAD

BSWMIX Units: lbs/ft^3 Dim: 5 ; s1: zone index
Desc: Array holding bulk-specific weight of sediment mixture stored in each redd zone after redd construction
Init: RDREAD

DGS Units: millimeters Dim: 18 ; s1: fraction index
Desc: Grain-size diameters used in constructing material size distributions
Init: BLKDAT

DND Units: millimeters Dim: 18 ; s1: fraction index
Desc: Nominal diameter of individual size fractions
Init: BLKDAT

FKV Units: ft^2/sec Dim: scalar ;
Desc: Kinematic viscosity of water at stream temperature
Init: SFPROP

FSLD Units: mg/liter Dim: 15 ; s1: fraction index
Desc: Concentration of suspended load fractions
Init: SUSLD

ITCNT Units: none Dim: scalar ;
Desc: Counts the number of time steps required to intrude the daily bed load mass into redd domain
Init: SEDRIV

LSF Units: none Dim: scalar ;
Desc: Largest sand-size fraction of sediment material moving through the system at any one time
Init: SFPROP

NSF Units: fraction Dim: scalar ;
Desc: Overall number of suspended sediment fractions
Init: BLKDAT

NSFIN Units: fraction Dim: scalar ;
Desc: Overall number of sediment fractions associated with bed load transport
Init: BEDCNC

NSFIT Units: fraction Dim: scalar ;
Desc: Overall number of sediment fractions in transport
Init: BLKDAT

NSFT Units: fraction Dim: scalar ;
Desc: Overall number of simulated sediment fractions.
Init: BLKDAT
This parameter includes both framework and matrix material fractions

PCF Units: decimal Dim: 18,4 ; s1: size fraction, s2: redd zone
Desc: Initial size distribution of individual redd zones
Init: RDREAD

PCFILL Units: decimal Dim: 15 ; s1: size fraction
Desc: Size distribution of bed load material
Init: BEDLD

PCK Units: decimal Dim: 20,12,18 ; s1: column, s2: layer, s3: size fraction
Desc: Size composition of sediment material stored in a cell
Init: INTKPB, RSTKP4

SGG Units: none Dim: scalar ;
Desc: Specific gravity of sediment fractions.
Init: BLKDAT
This parameter is assumed to be the same for all fractions

SV Units: ft/s Dim: scalar ;
Desc: Mean water velocity in subsection
Init: HYREAD

SWS Units: ft/minute Dim: 18 ; s1: fraction index
Desc: Settling velocity of suspended sediment fractions.
Init: SFPROP
This variable is computed for fractions in transport only

SWSADJ Units: none Dim: scalar

Desc: Multiplies ASWS3 (the weighted mean sand settling velocity) to adjust for the fraction of terminal velocity obtained in the intragravel environment
Init: DRIVR2

SWW
Units: lbs/ft^3 Dim: scalar ;
Desc: Specific weight of water at stream temperature
Init: SFPROP

TBLDPLF
Units: lbs/ft/day Dim: scalar ;
Desc: Total bed load rate per foot in subsection
Init: BEDLD

TBDLDSS
Units: tpd Dim: scalar ;
Desc: Total bed load rate in subsection
Init: BEDLD

UDSTB2
Units: none Dim: logical
Desc: Logical variable (TRUE indicates that all disturbed zone cells are initially in blocked status, FALSE indicates that undisturbed zone is not initially blocked)
Init: DRIVR2

WK
Units: lbs/ft^3 Dim: 20,12,10 ; s1: column, s2: layer, s3: size fraction
Desc: Weight of individual fractions present in a cell
Init: INTKPB, RSTKP4

WSS
Units: ft/ft Dim: scalar ;
Desc: Water energy slope
Init: HYREAD

ZETA
Units: none Dim: scalar ;
Desc: Dimensionless depth at which bed sediment concentration is computed
Init: BLKDAT

Common Block Name: SDBLK2
Purpose: Transfer variables used to control and characterize transport and deposition of fine sediment within the redd
Used in Modules: ADTFNS, BEDMOV,BLKDAT, CHKBKG, CNTOUR, CSOLVR, GWDRIV, IGFRED, INITHC, INTKPB, MAPBKG, QCALC, RDREAD, RSTKP4, SEDRIV, TABLE, TGSEAL, TOD, UPDATE, VTABLE

BLOCK Units: none Dim: 0:21,0:13 ; s1: column no., s2: layer no.
Desc: Array holding filling status of cells
Init: BLKDAT

CBADJ Units: none Dim: scalar ;
Desc: Parameter controlling concentration of infiltrating fines at the stream-redd interface
Init: RDREAD

DELC Units: parts/part Dim: 20,12,3 ; s1: column no., s2: layer no., s3: size fraction
Desc: Volumetric concentration of sediment fines deposited in a cell during a day
Init: SEDRIV

DELFNS Units: grams/cc Dim: 20,12 ; s1: column no., s2: layer no.
Desc: Concentration of clay-silt mixture added to a cell during a day
Init: ADTFNS

IDATFL Units: days Dim: scalar ;
Desc: Integer variable that flags the day when the redd void zone is filled. This flag is used in module SEDRIV to set up initial conditions in the filled zone at the time of filling.
Init: BEDMOV

SEDC1 Units: parts/part Dim: 0:21,0:13,2 ; s1: column no., s2: layer no., s3: time level
Desc: Volumetric concentration of suspended clay in a cell
Init: SEDRIV

SEDC2 Units: parts/part Dim: 0:21,0:13,2 ; s1: column no., s2: layer no., s3: time level
Desc: Volumetric concentration of suspended silt in a cell
Init: SEDRIV

SEDC3 Units: parts/part Dim: 0:21,0:13,2 ; s1: column no., s2: layer no., s3: time level
Desc: Volumetric concentration of suspended sand in a cell
Init: SEDRIV

VSADJ Units: none Dim: scalar ;
Desc: Dimensionless parameter used to control rate of intragravel sediment settling
Init: BLKDAT

Common Block Name: SDBLK3
Purpose: Transfer variables used to control and characterize transport and deposition of fine sediment within the redd
Used in Modules: ADTFNS, BEDCNC, BEDLD, BEDMOV, BLKDAT, CHKBKG, CNTOUR, CSOLVR, DRIVR2, GWDRIV, HYREAD, INITHC, INTKPB, MAPBKG, QCALC, RSTKP4, SEDPRP, SEDRIV, TABLE, TOD, UPDATE, VTABLE

BDGD16 Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 16 percent of the active bed particles are smaller
Init: SEDPRP

BDGD40 Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 40 percent of the active bed particles are smaller
Init: SEDPRP

BDGD50 Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 50 percent of the active bed particles are smaller
Init: SEDPRP

BDGD60 Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 60 percent of the active bed particles are smaller
Init: SEDPRP

BDGD90 Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 90 percent of the active bed particles are smaller
Init: SEDPRP

BSFRD Units: none Dim: scalar ;
Desc: Bed stability factor at redd for current day
Init: HYREAD

DDS Units: feet Dim: scalar ;
Desc: Mean water depth, over 10 ft. interval, at the down stream cross section having the same lateral position as the redd under simulation
Init: HYREAD

DSTRD Units: feet Dim: scalar ;
Desc: Distance of down stream end of redd from down stream cross section
Init: HYREAD

DUS Units: feet Dim: scalar ;
Desc: Mean depth in subsection at upstream cross section
Init: HYREAD

HRAD Units: feet Dim: scalar ;
Desc: Hydraulic radius of subsection
Init: HYREAD

RLN Units: feet Dim: scalar ;
Desc: Reach length, or mean distance between cross section
Init: HYREAD

STVM Units: ft/s Dim: scalar ;
Desc: Mean water velocity in subsection

Init: HYREAD

SUQ Units: $ft^3/s/ft$ Dim: scalar ;
Desc: Unit discharge of subsection
Init: HYREAD

SUMUQ2 Units: $ft^3/s/ft$ Dim: scalar ;
Desc: Sum of subsection unit discharges for upstream cross section
Init: HYREAD

TLD Units: tpd Dim: scalar ;
Desc: Total sediment load for day
Init: HYREAD

TPDSEDL Units: tpd Dim: 1:15 ; s1: size fraction
Desc: Sediment transport rate for each size fraction for current day
Init: HYREAD

TQD Units: ft^3/s Dim: scalar ;
Desc: Total water flow at upstream cross section for current day
Init: HYREAD

Common Block Name: SDBLK4
Purpose: Transfer variables used to control and characterize transport and deposition of fine sediment within the redd
Used in Modules: ADTFNS, BEDCNC, BEDLD, BEDMOV, BLKDAT, CHKBKG, CNTOUR, CSOLVR, DRIVR2, GWDRIV, HYREAD, INITHC, INTKPB, MAPBKG, QCALC, RDREAD, RSTKP4, SEDPRP, SEDRIV, TABLE, TGSEAL, TOD, UPDATE, VTABLE

BDFC
Units: fraction Dim: 1:15 ; s1: size fraction
Desc: Gradation, mass fraction finer, of active bed material
Init: HYREAD

BDLDSS
Units: tpd Dim: 1:15 ; s1: size fraction
Desc: Sediment transport rate for each size fraction for current day
Init: HYREAD

BDLD15
Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 15 percent of the bed load particles are smaller
Init: BEDLD

BDLD50
Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 50 percent of the bed load particles are smaller
Init: BEDLD

BDLD85
Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 85 percent of the bed load particles are smaller
Init: BEDLD

BDLD90
Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 90 percent of the bed load particles are smaller
Init: BEDLD

BDGD90
Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 90 percent of the active bed particles are smaller
Init: SEDPRP

DSTD15
Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 15 percent of the disturbed zone particles are smaller
Init: RDREAD

DSTD50
Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 50 percent of the disturbed zone particles are smaller
Init: RDREAD

DSTD90
Units: millimeters Dim: scalar ;
Desc: Particle diameter for which 90 percent of the disturbed zone particles are smaller
Init: RDREAD

PSFPIT
Units: none Dim: scalar
Desc: Specifies particle size distribution of material filling the pit zone, PSFPIT= 1 - undisturbed zone, 2- disturbed zone,

```
                3- egg zone, 4- HEC-6 active bed material
          Init: RDREAD

SDLDSS    Units: #/s                Dim: 1:15 ; s1: size fraction
          Desc: Suspended sediment transport rate for subsection
          Init: BEDLD

SLOAD     Units: part/part          Dim: 1:15 ; s1: size fraction
          Desc: Suspended sediment concentration at the water
                column/substrate interface
          Init: SUSLD

STBD      Units:  #/ft              Dim:  scalar ;
          Desc: Mass of material, satisfying the seal triggering criterium,
                which flows over the redd in one time step
          Init: TGSEAL

TBD       Units: tpd                Dim:  scalar ;
          Desc: Total bed load rate
          Init: BEDLD
```

Common Block Name: STBLK2
Purpose: Transfer variables used to characterize stream flow properties and to control stream flow routing
Used in Modules: BEDMOV, BLKDAT, DODRIV, DOXBED, HYREAD, INTERP, RDDSED, RDDWAT, SEDBED, SFPROP

QYSTDY Units: cfs Dim: scalar ;
Desc: Stream flow discharge during previous day
Init: STREAM

QD Units: feet Dim: scalar ;
Desc: Stream flow discharge during previous day
Init: STDRIV

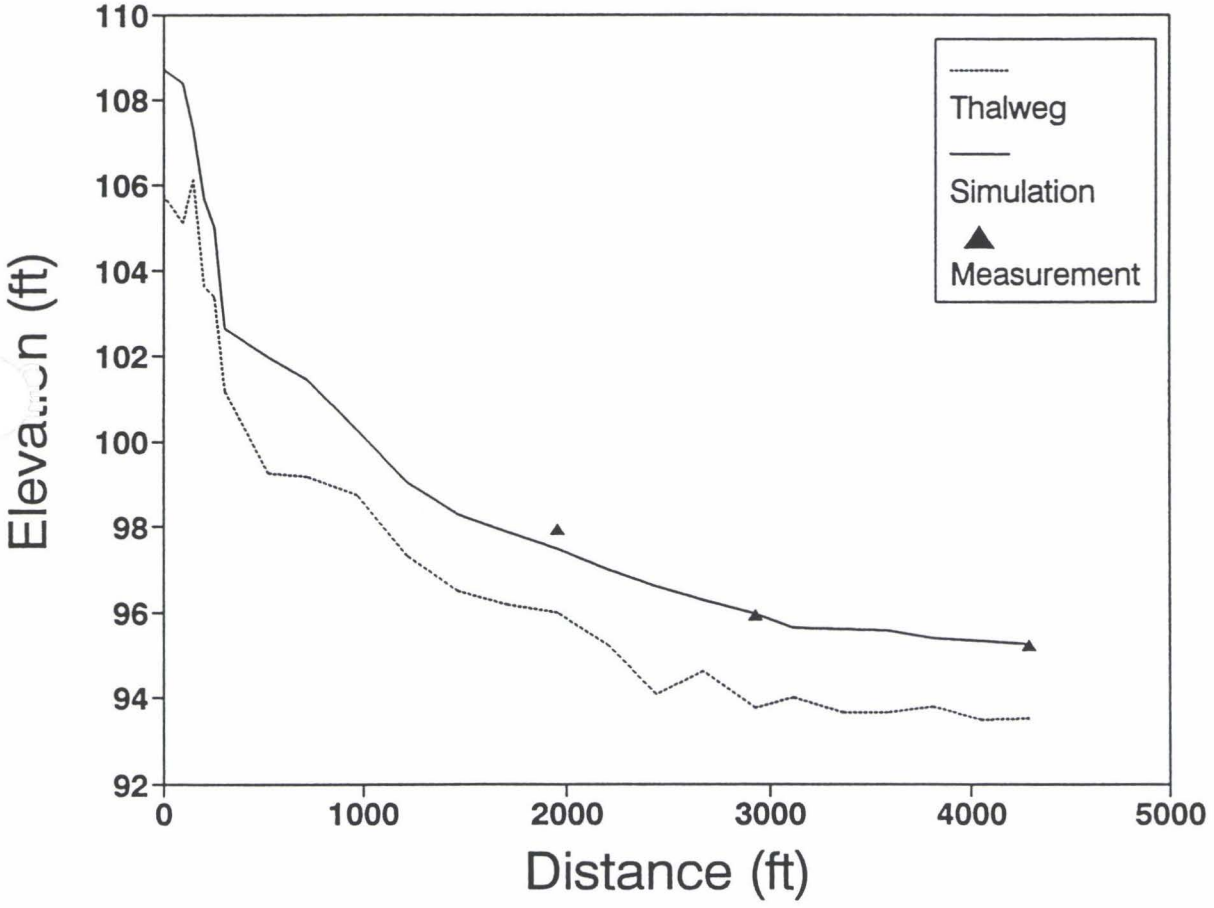
TEMP Units: Celsius degrees Dim: scalar ;
Desc: Daily mean water temperature
Init: DRIVER

APPENDIX A

Stage Profile Simulations

Dissolved Oxygen and Water Temperature Simulations

jd-92


110
108
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92
Elevation (ft)
0
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2000
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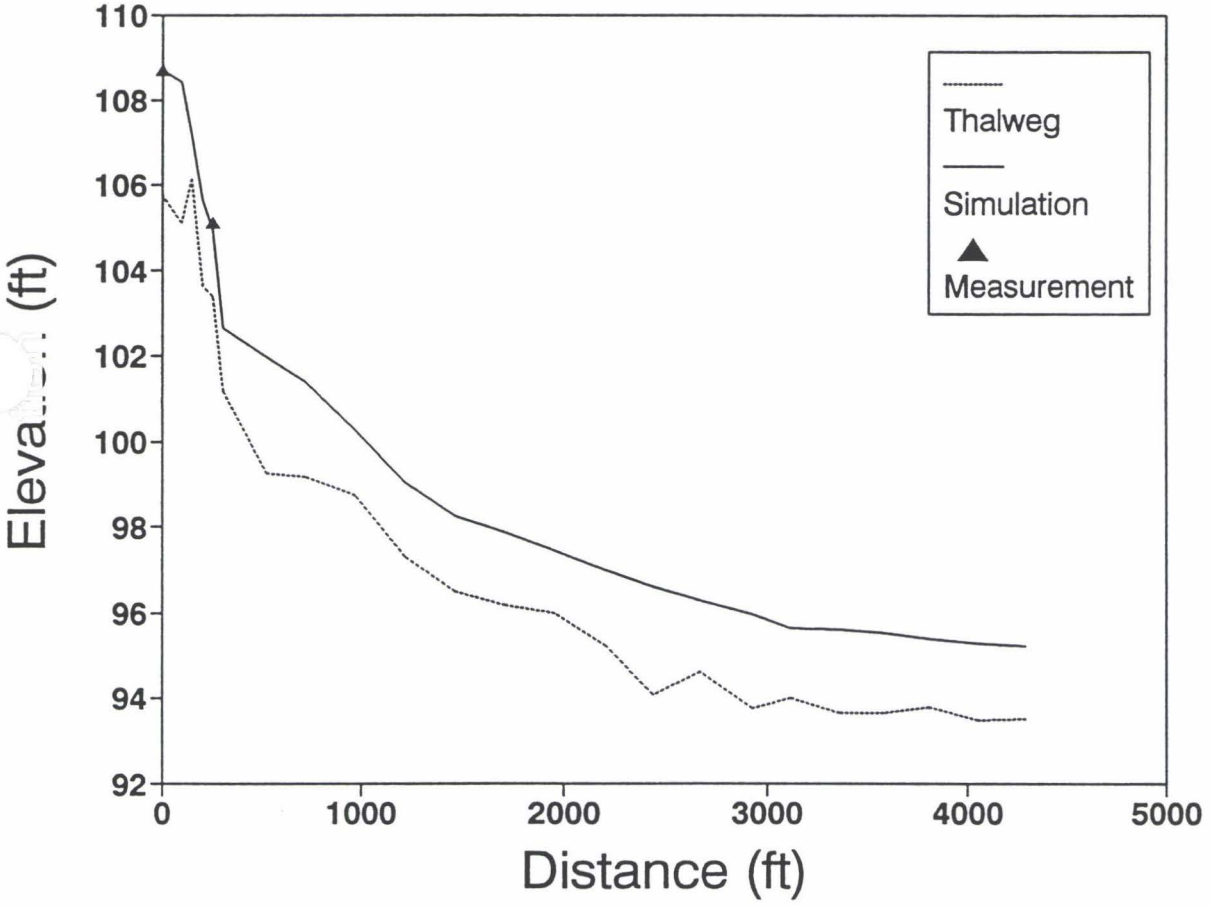
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-93


110
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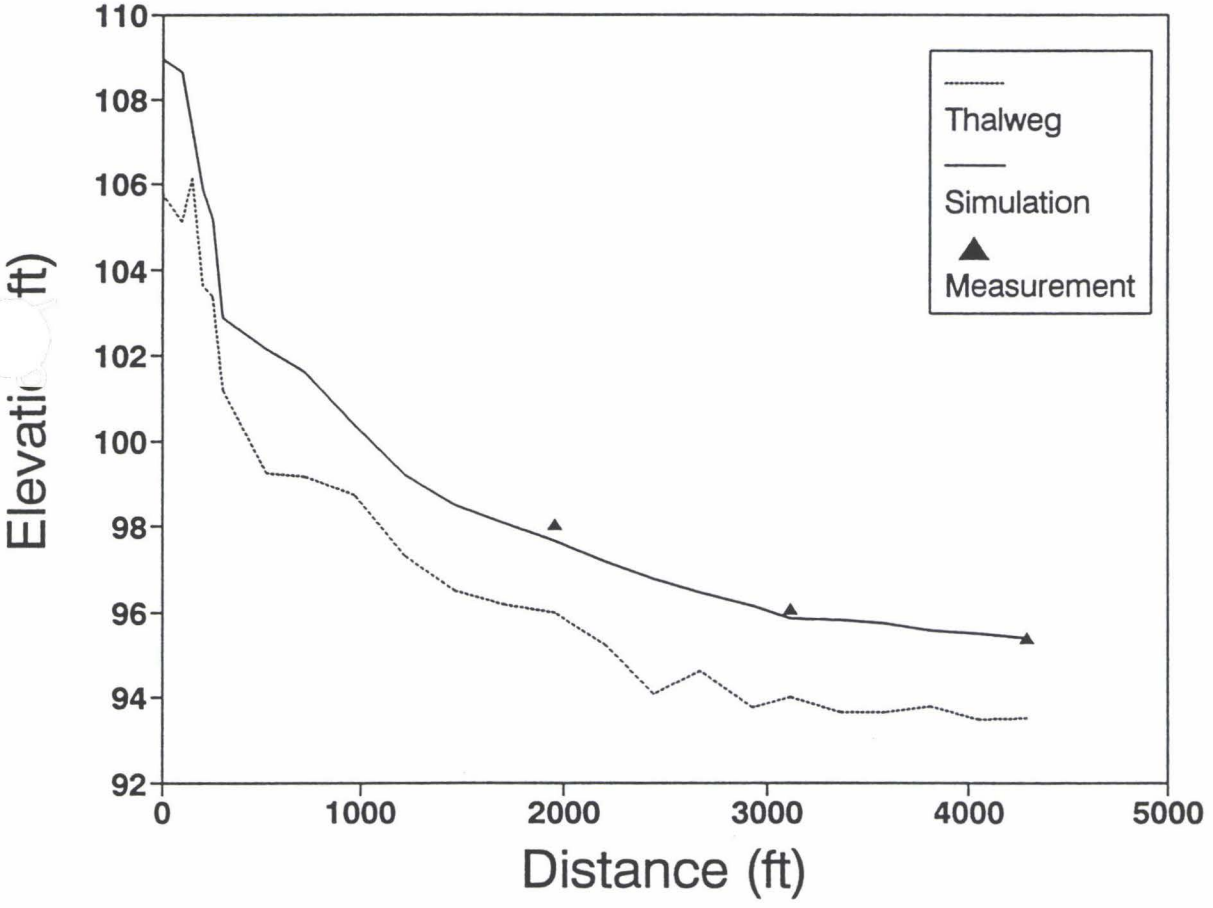
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-98


110
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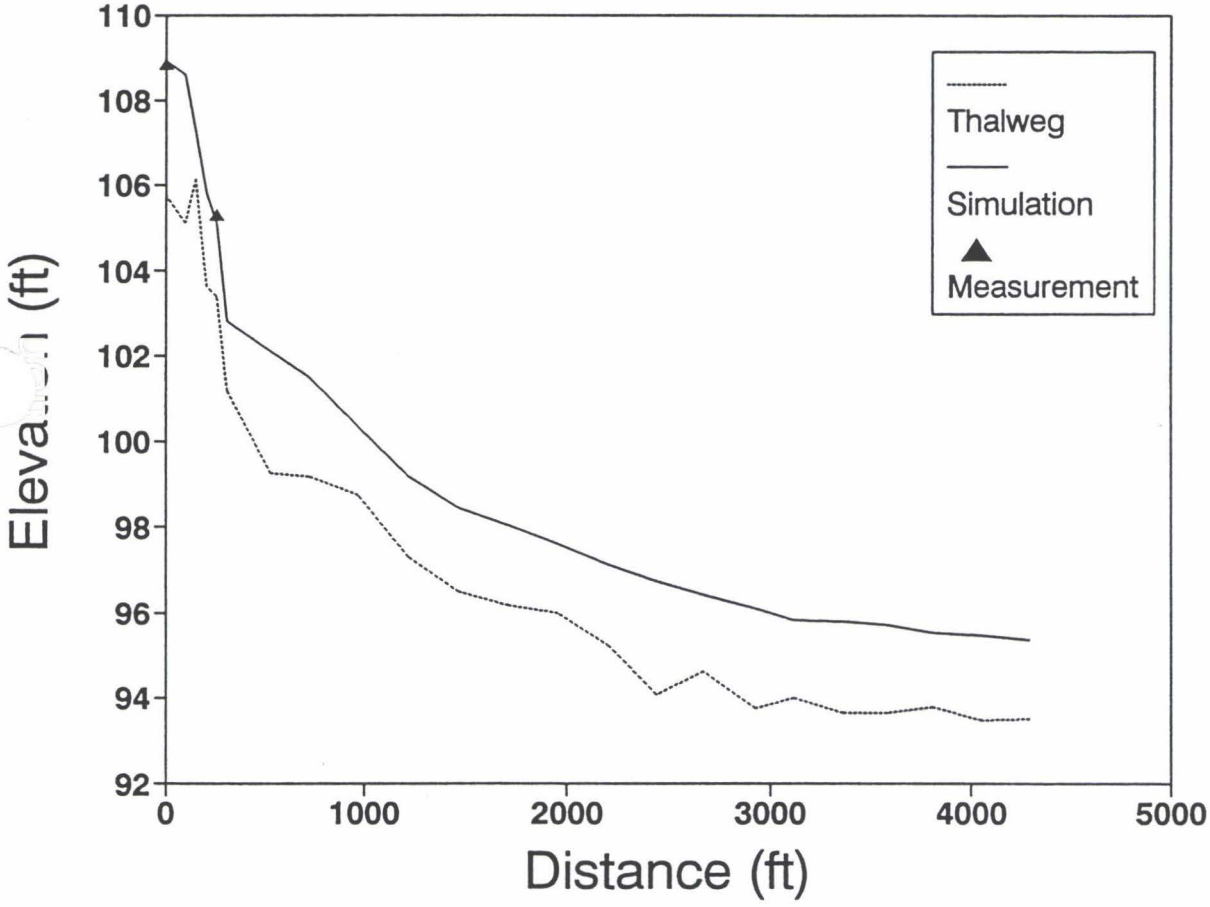
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-99


110
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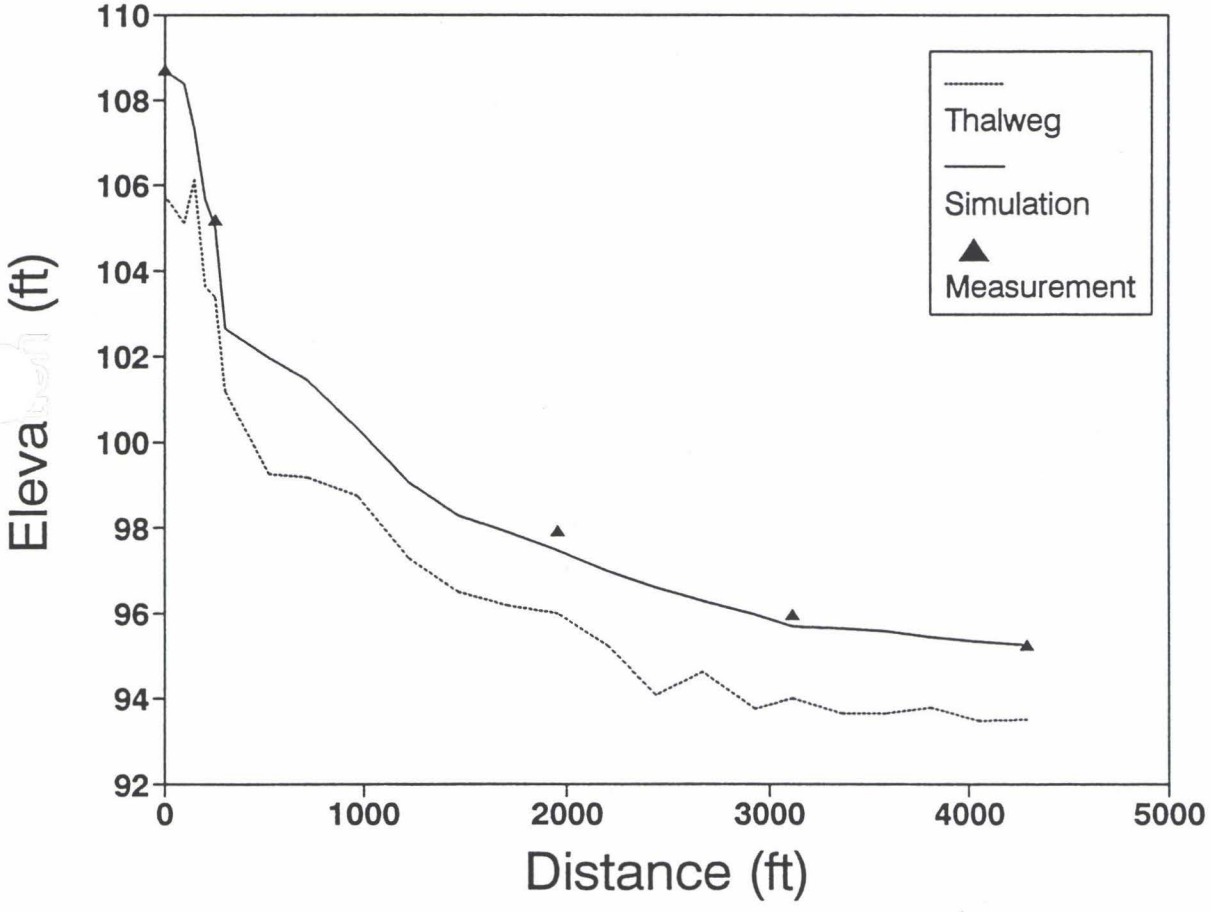
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-106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102
100
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94
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Elevation (ft)
0
1000
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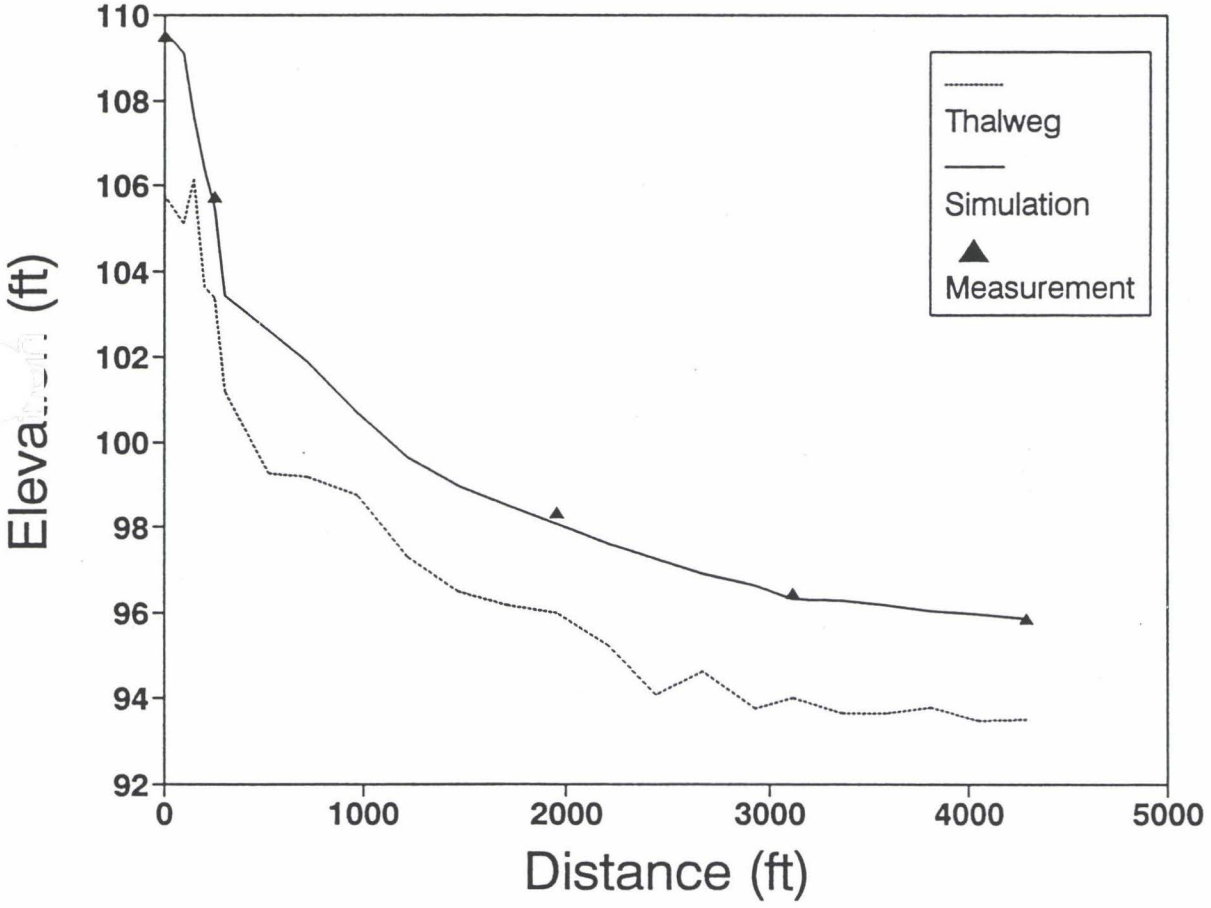
3000
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-114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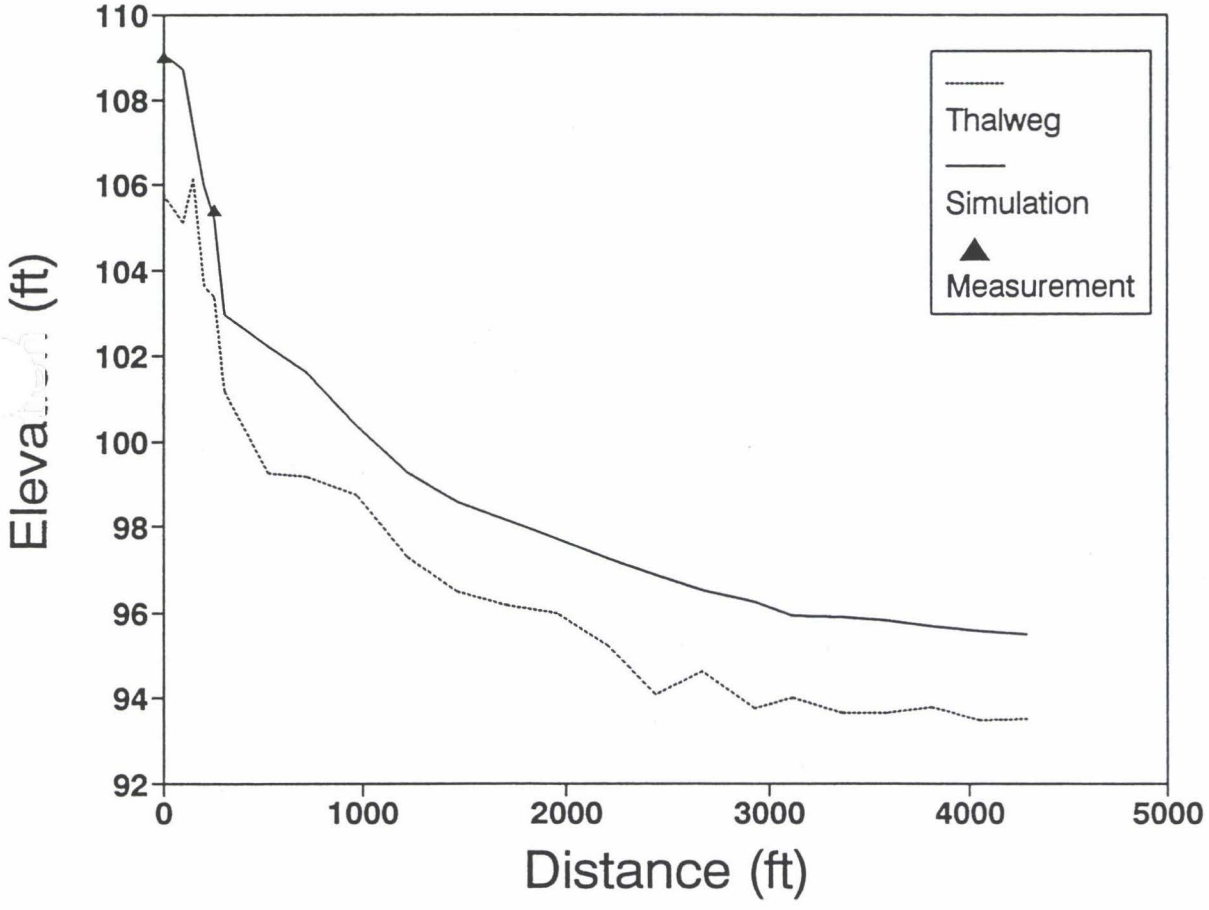
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-120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92
Elevation (ft)
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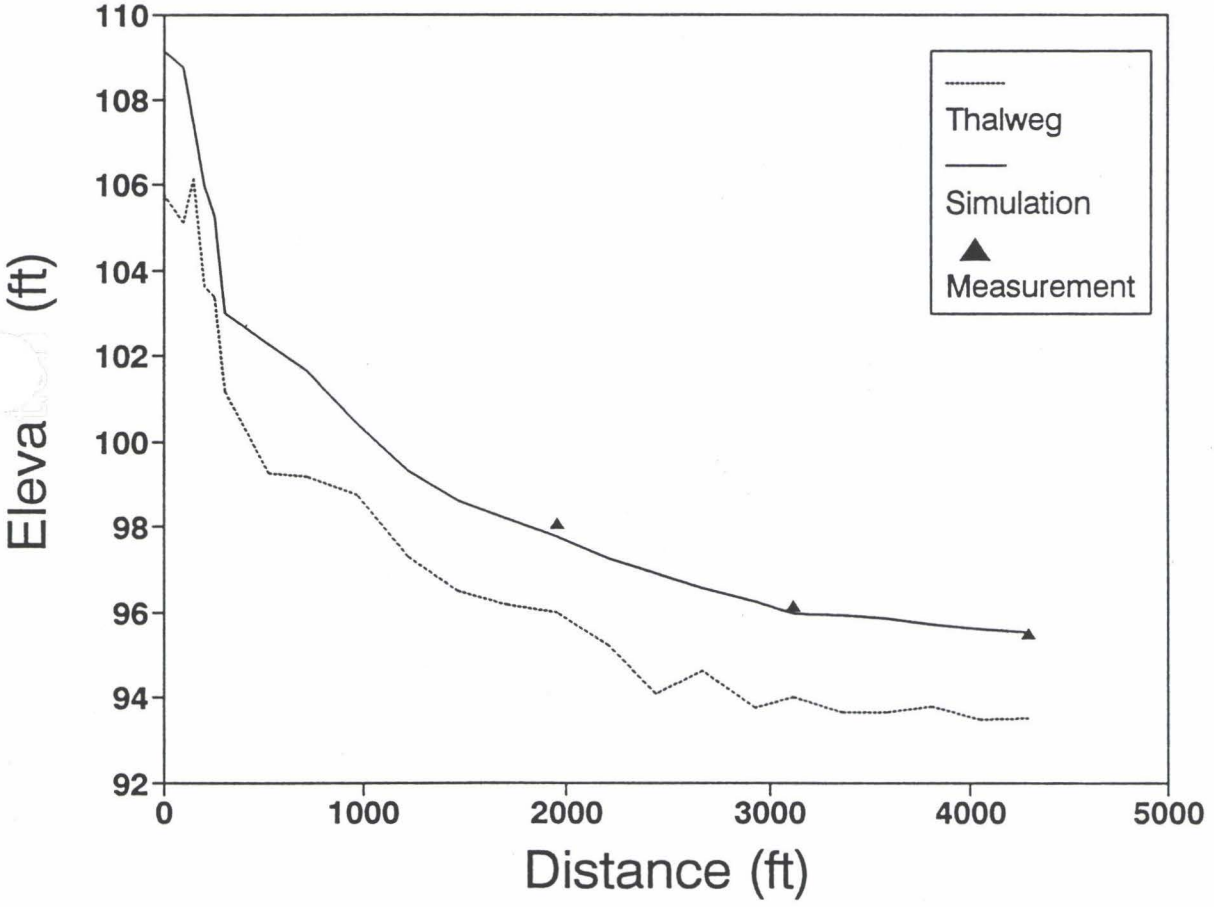
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-121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92
Eleva (ft)
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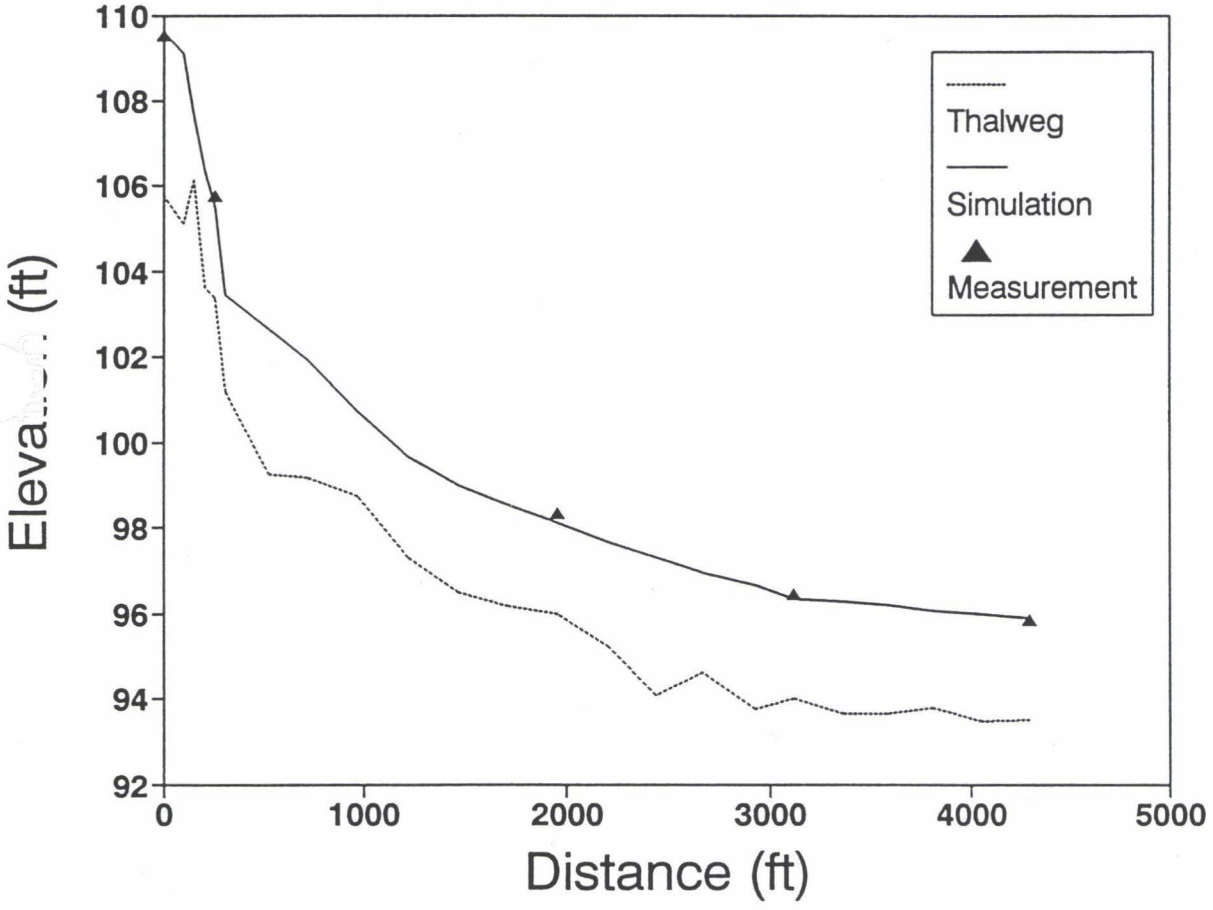
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-127


110
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94
92
Elevation (ft)
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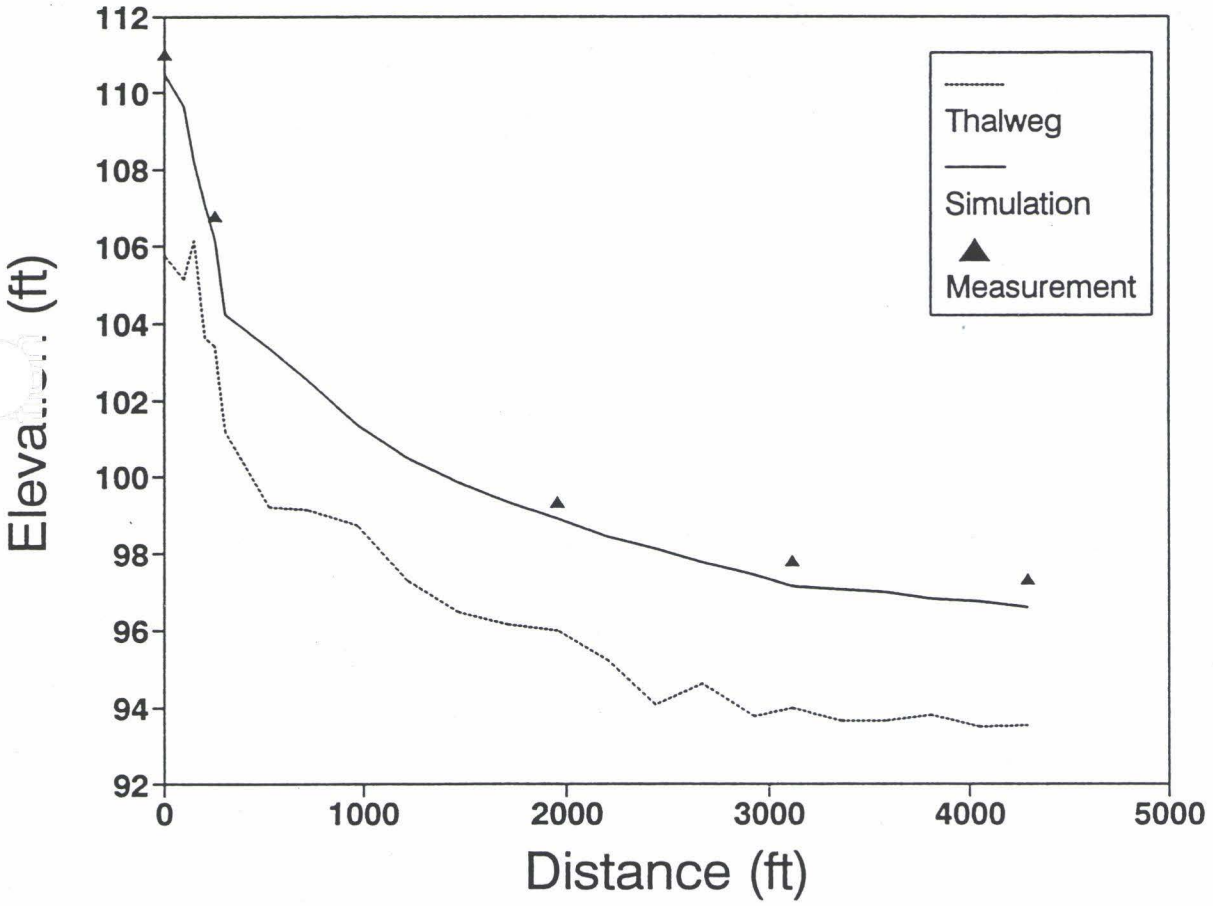
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-128


112
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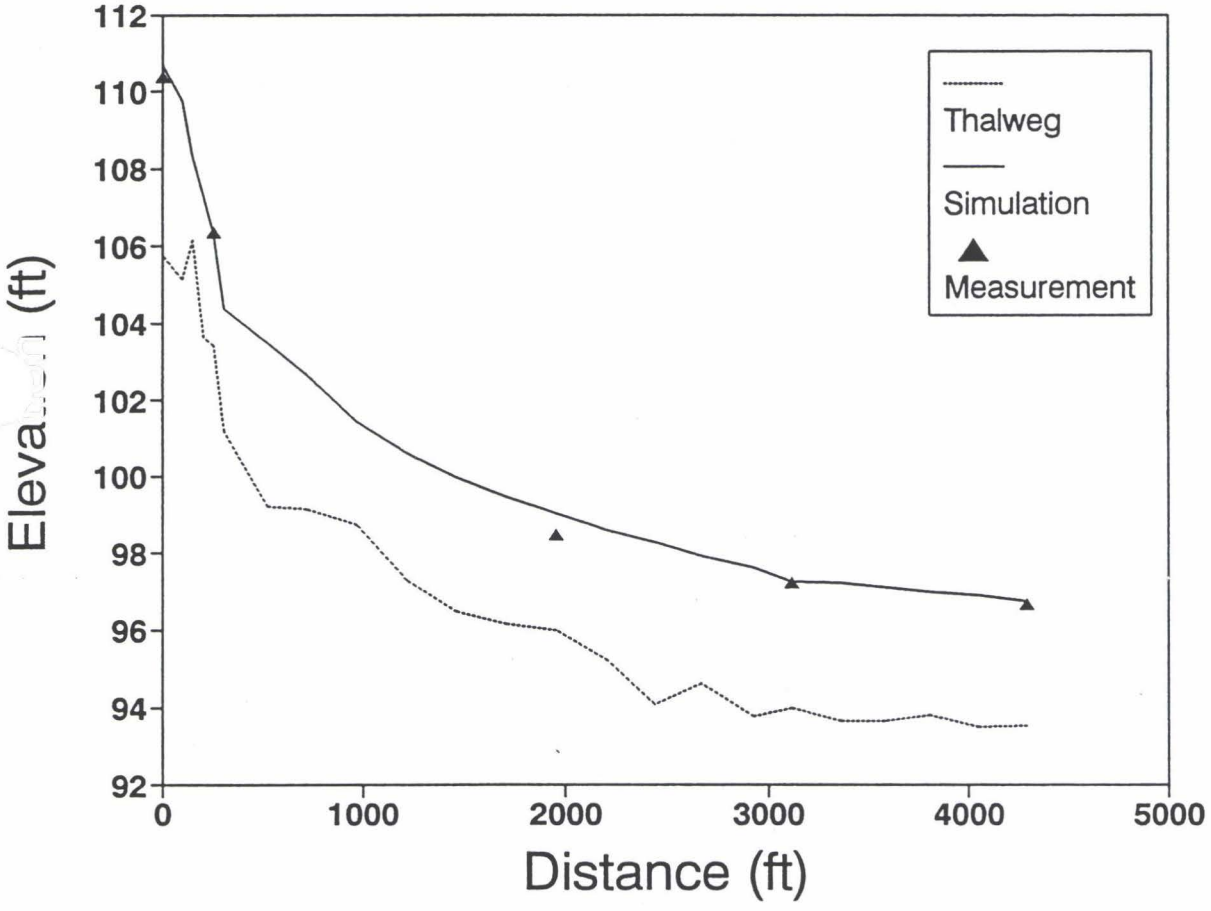
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-129


112
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Elevation (ft)
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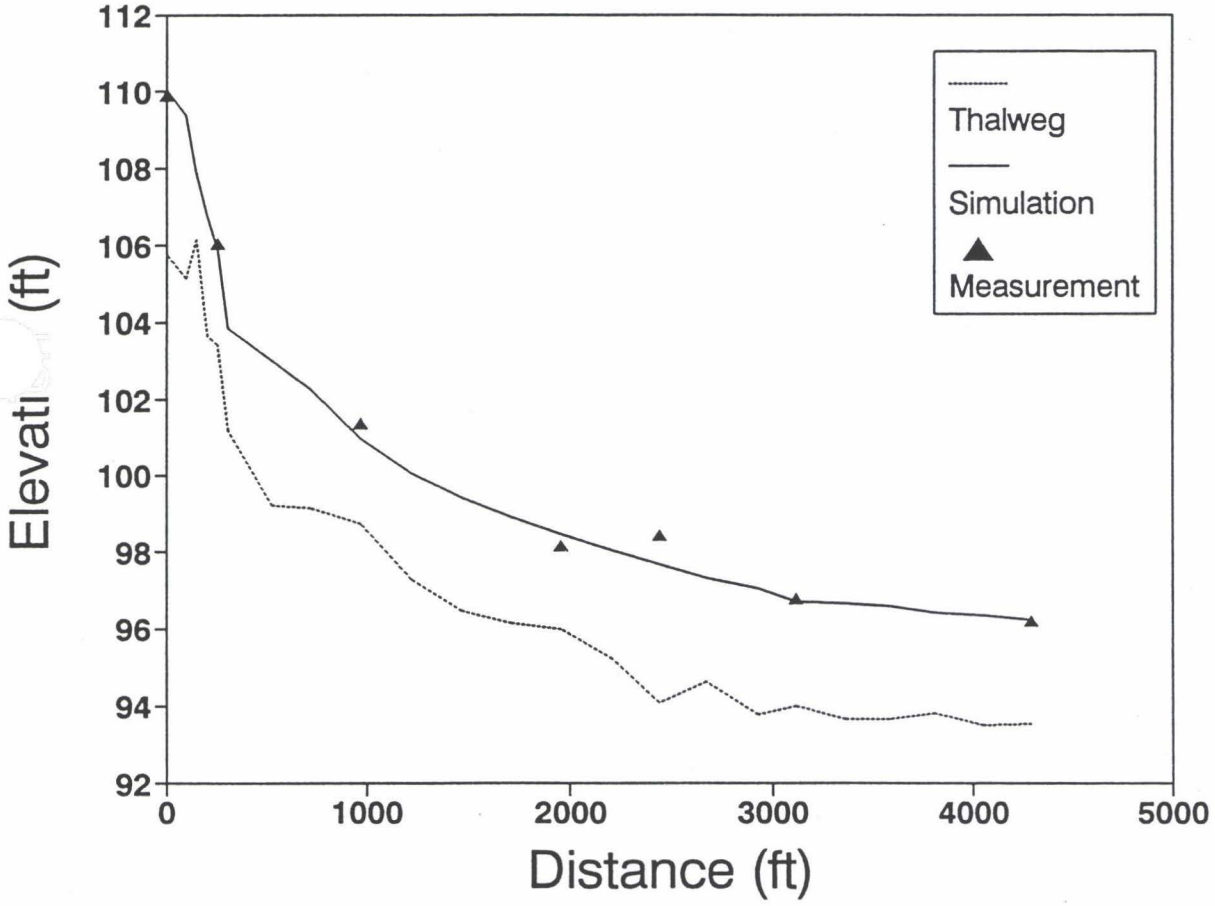
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-135


112
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100
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94
92
Elevati (ft)
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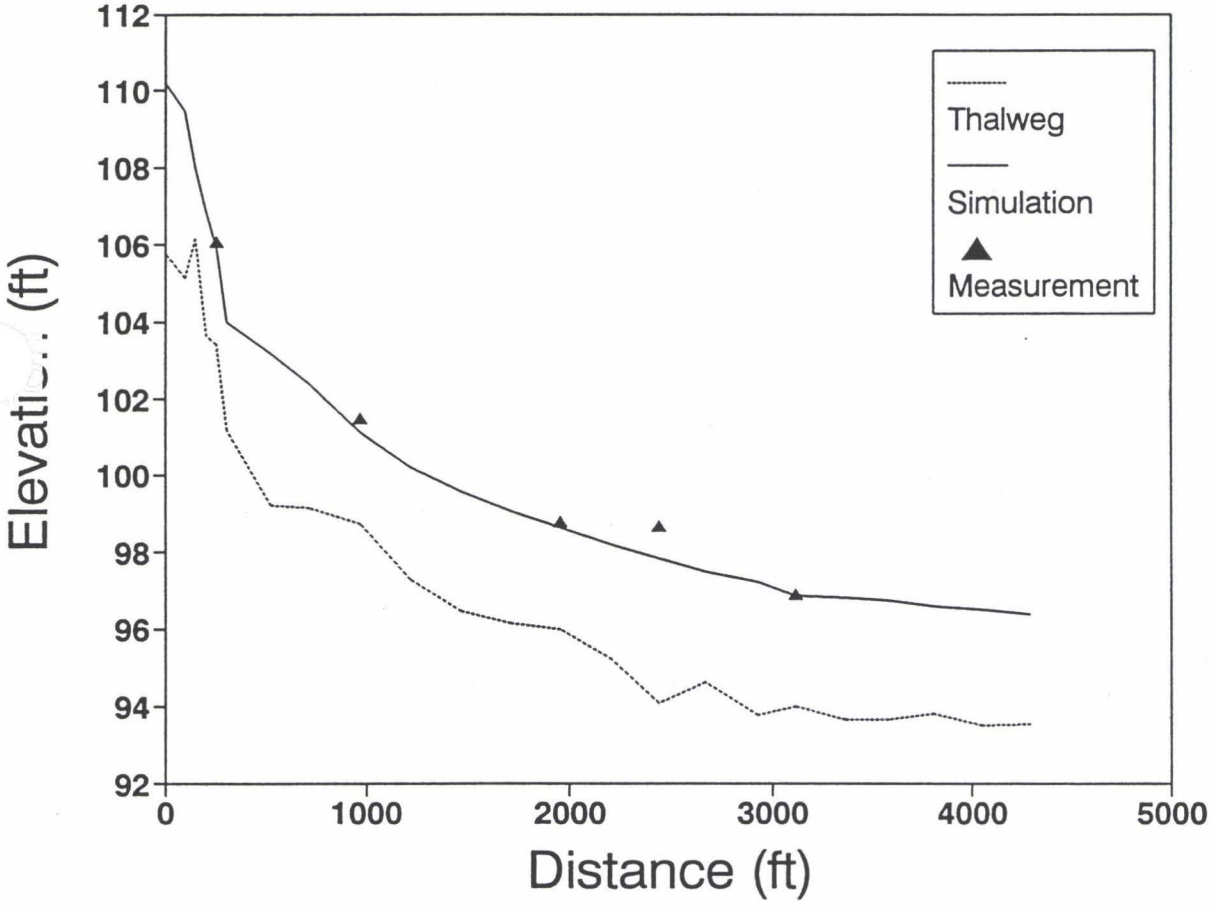
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-136


Elevation (ft)
112
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92
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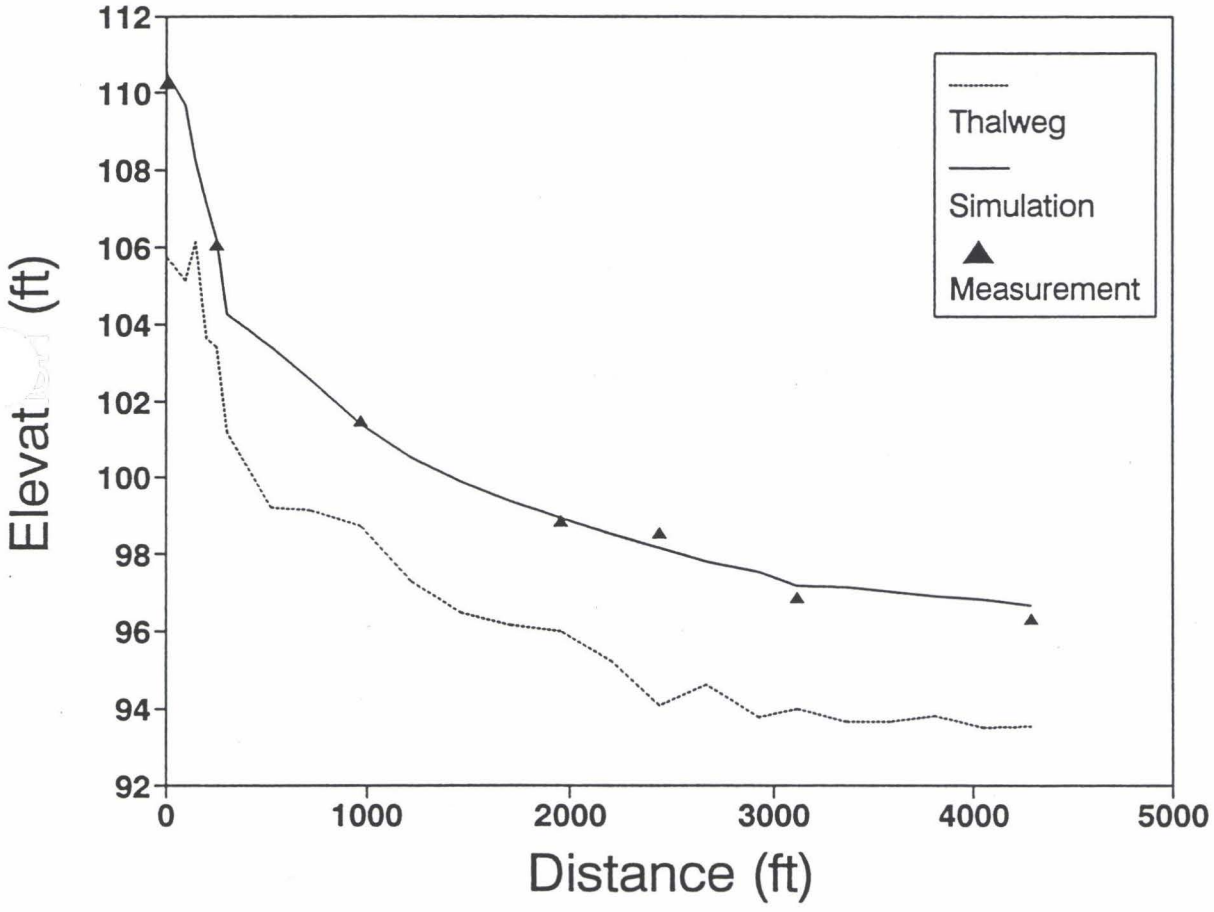
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-141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Elevation (ft)
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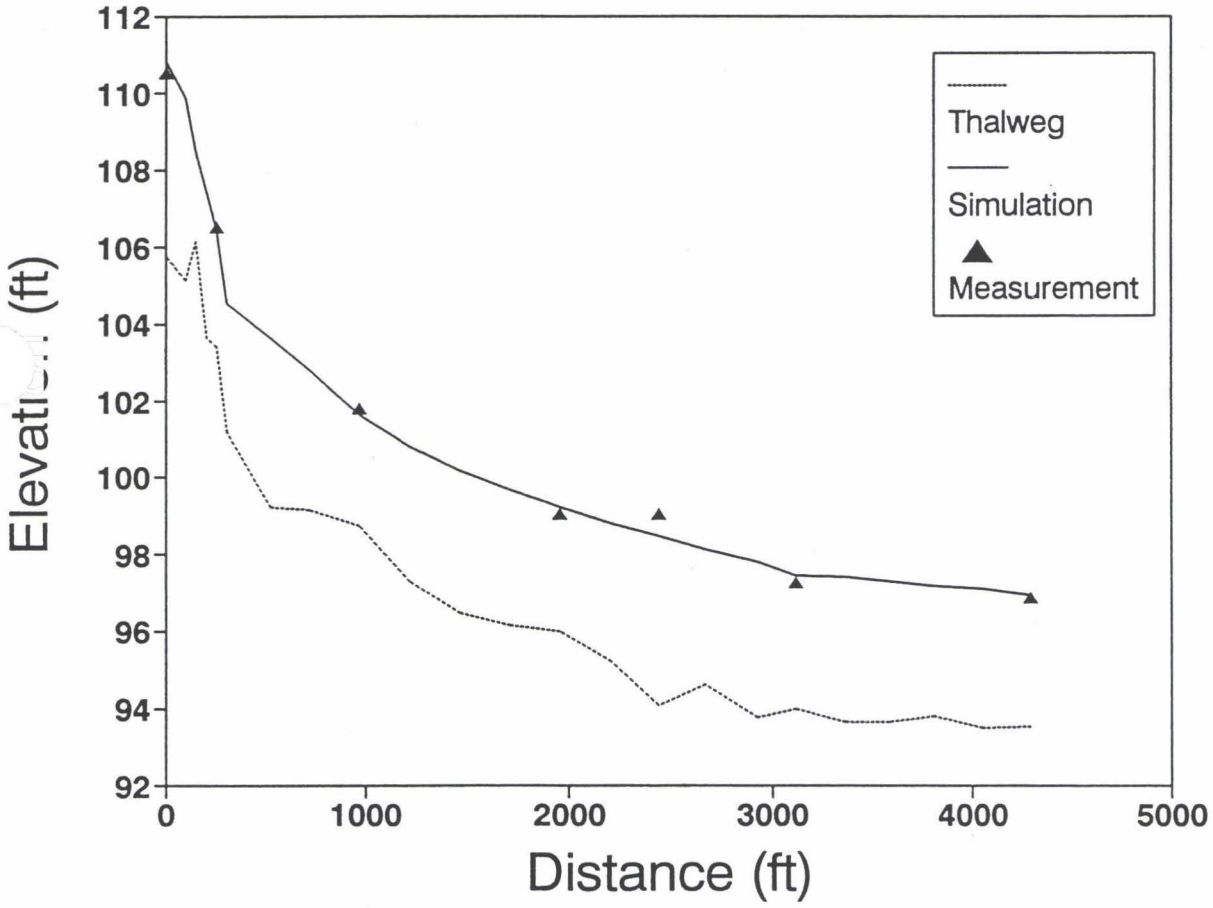
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-142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Elevation (ft)
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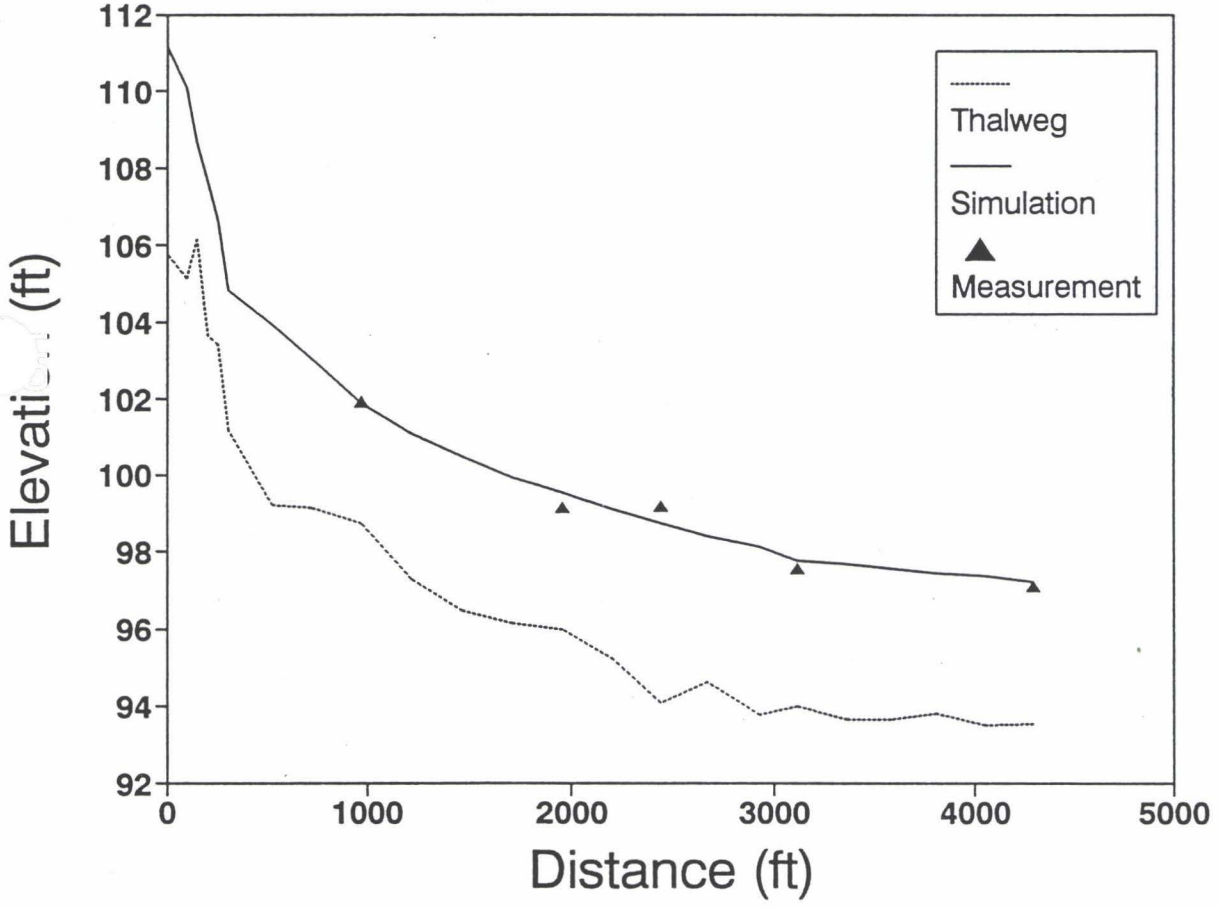
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-143


112
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Elevation (ft)
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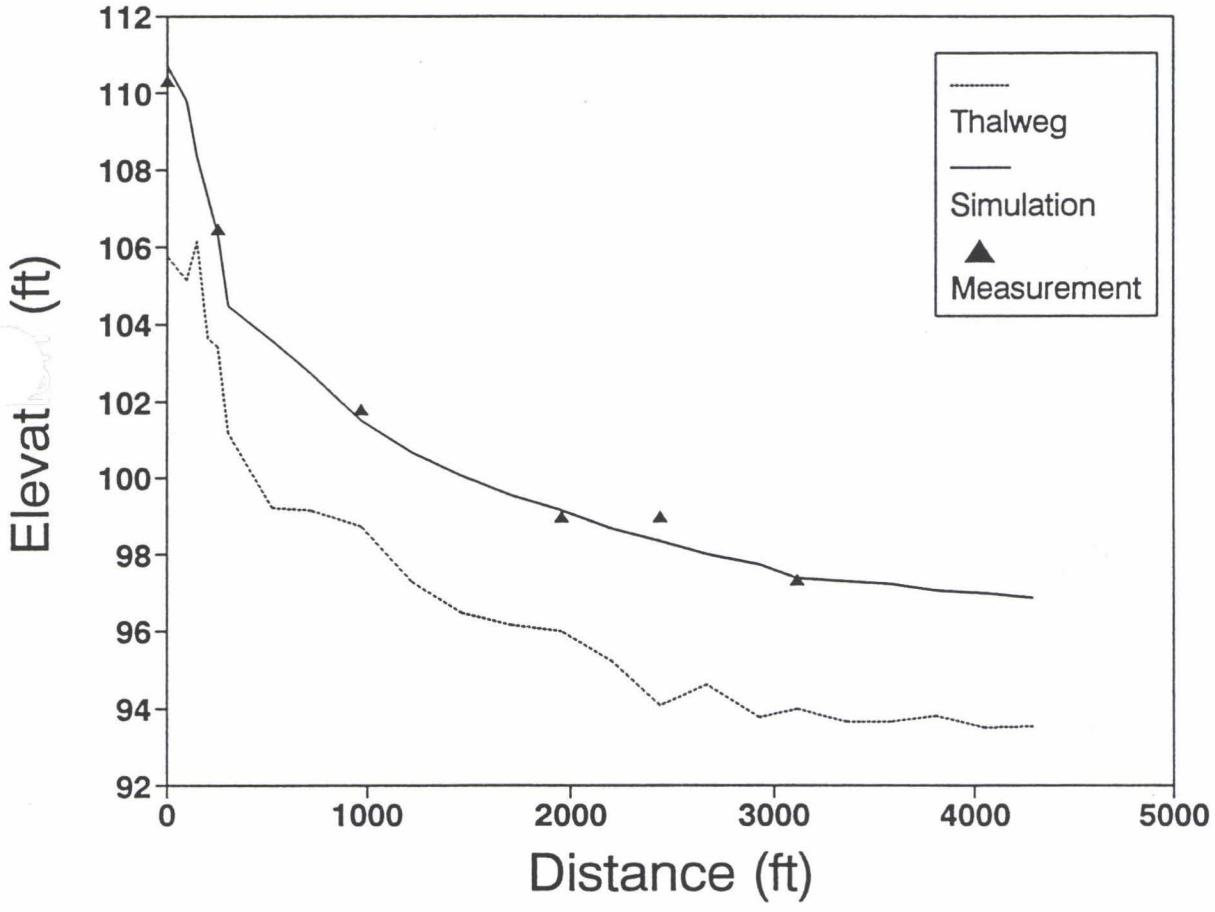
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-149


112
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96
94
92
Elevat (ft)
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2000
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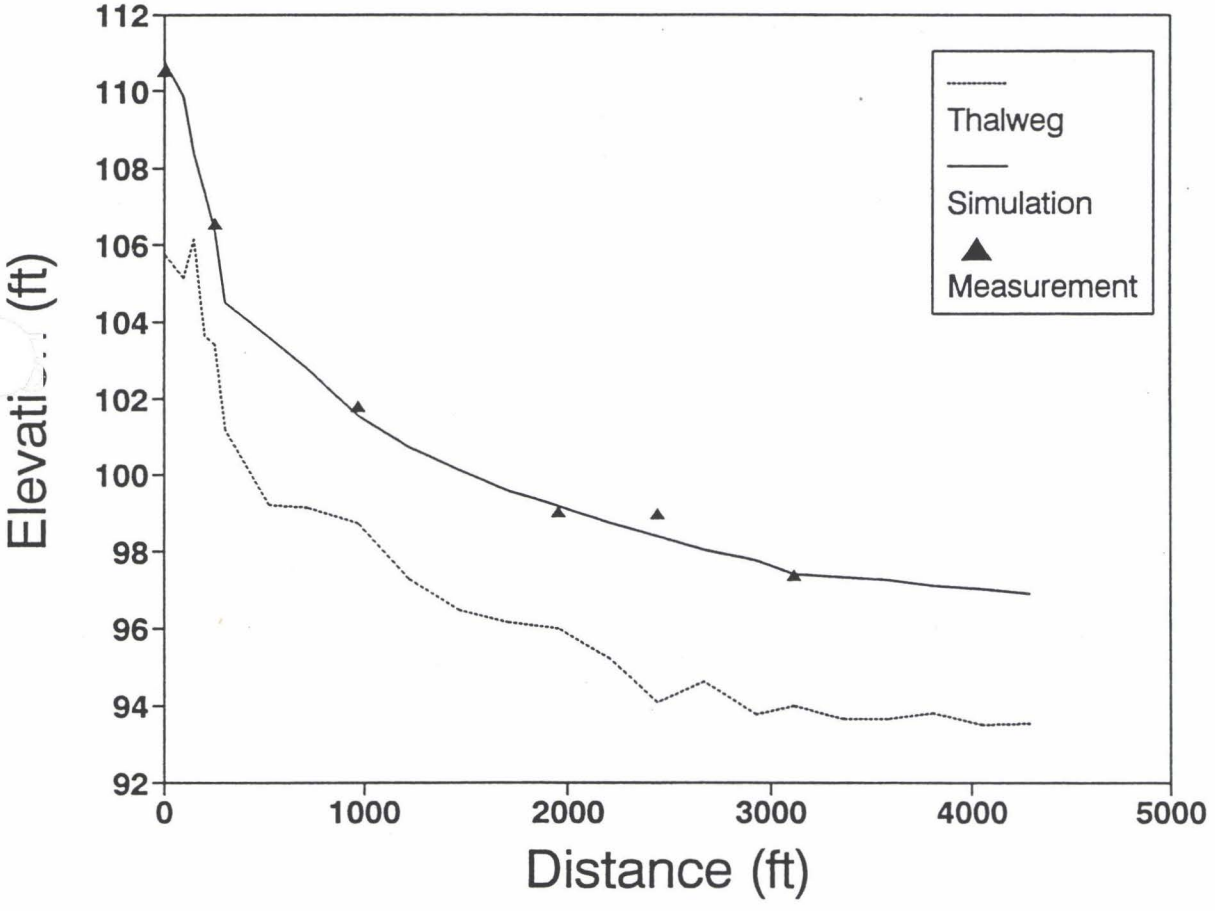
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-150


112
110
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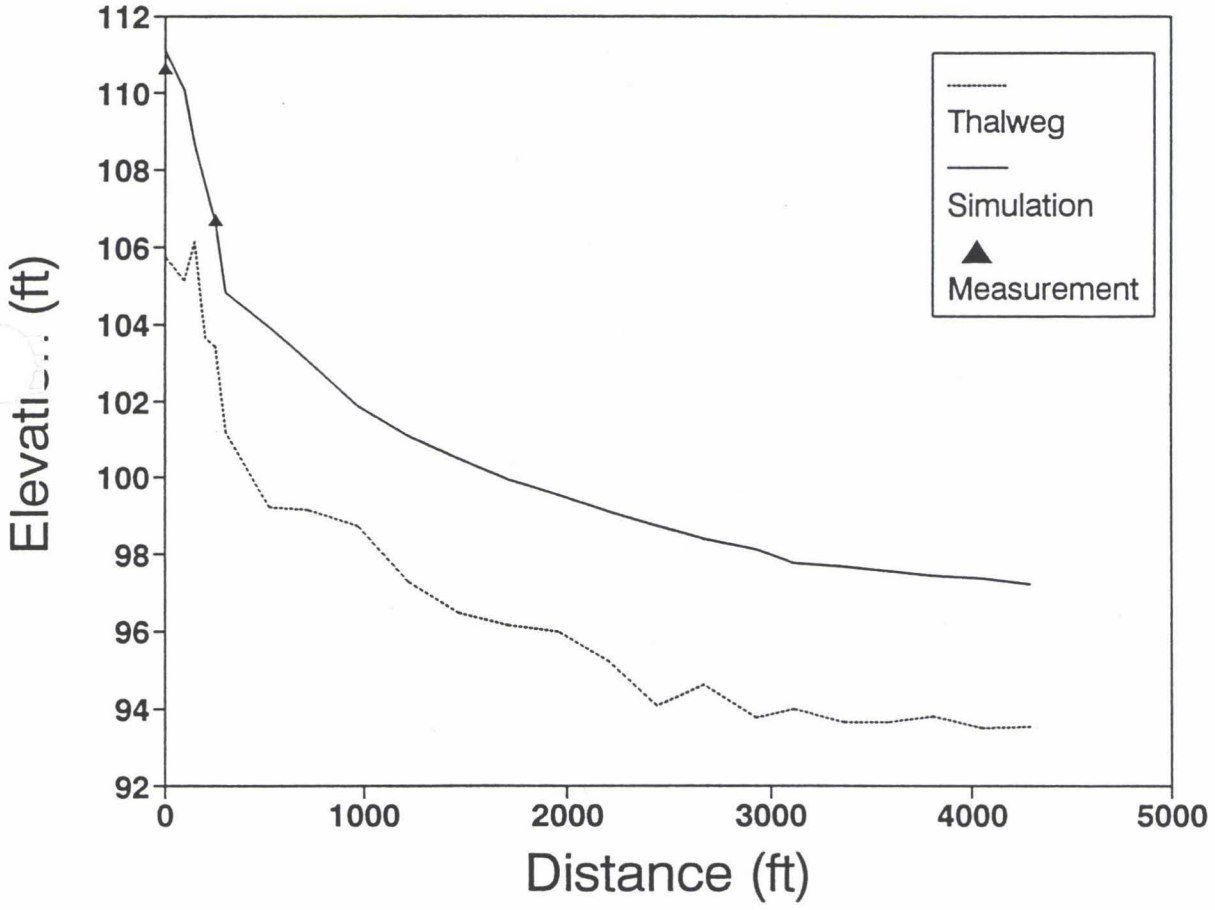
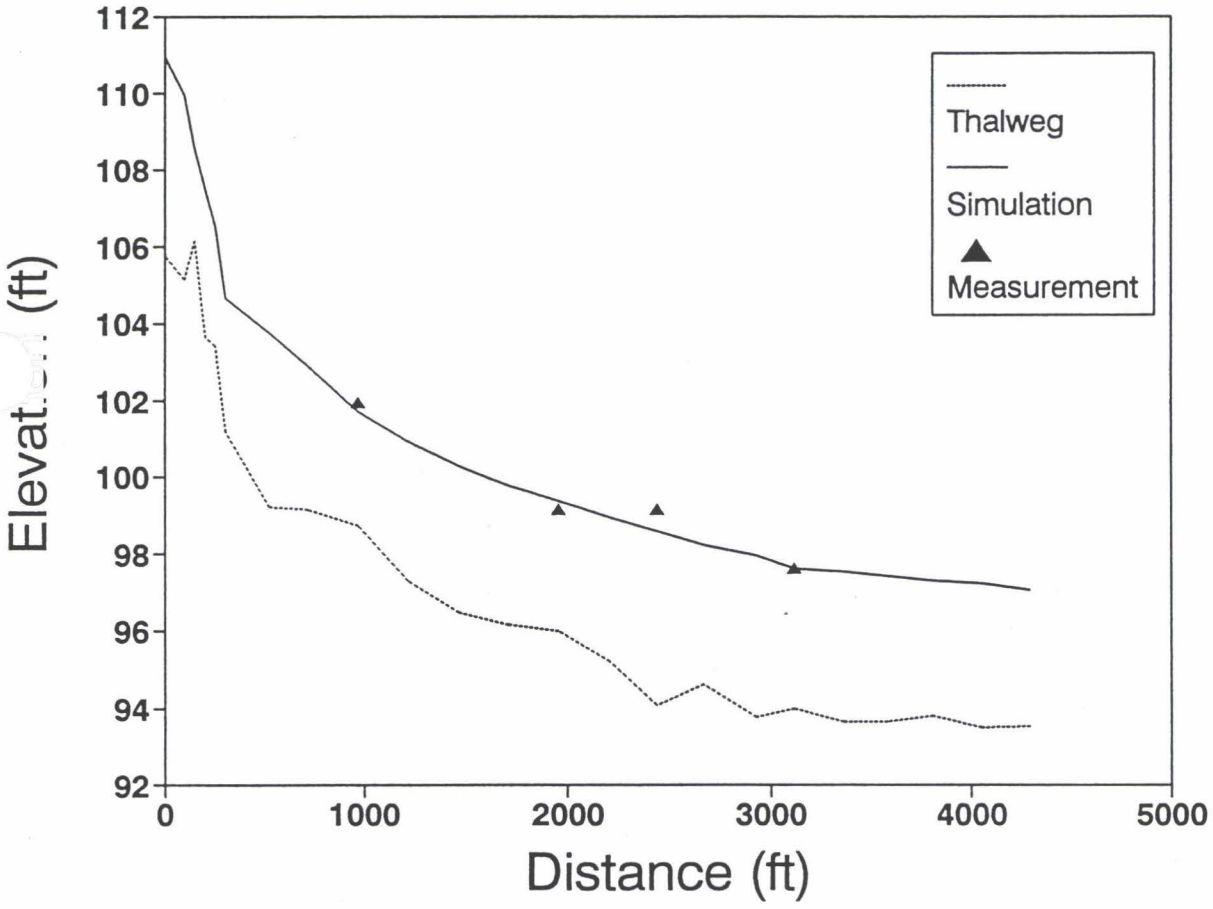
94
92
Elevati... (ft)
0
1000
2000
3000
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

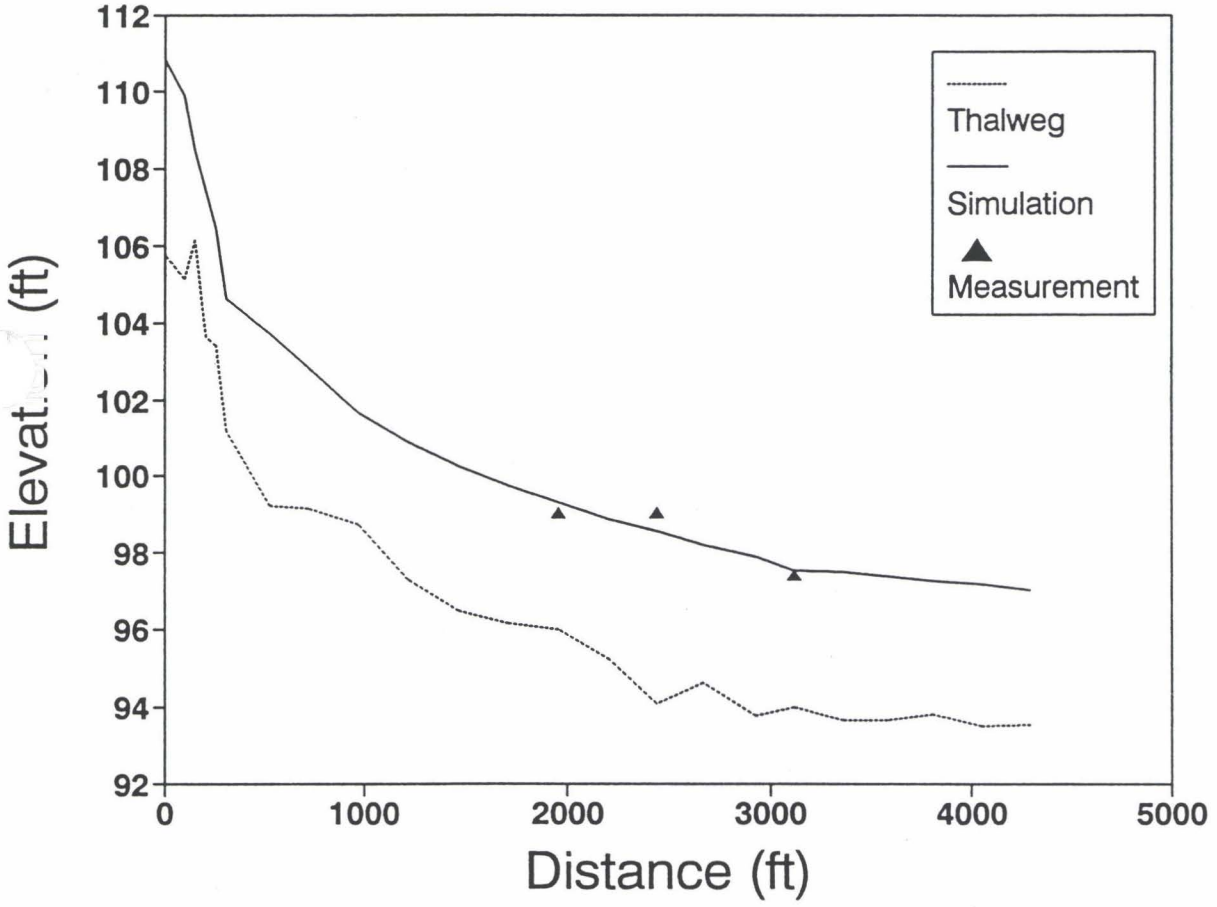
jd-155


Elevation (ft)
112
110
108
106
104
102
100
98
96
94
92
0
1000
2000
3000
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-156


112
110
108
106
104
102
100
98
96
94
92
Elevat... (ft)
0
1000
2000
3000
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-162


112
110
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106
104
102
100
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94
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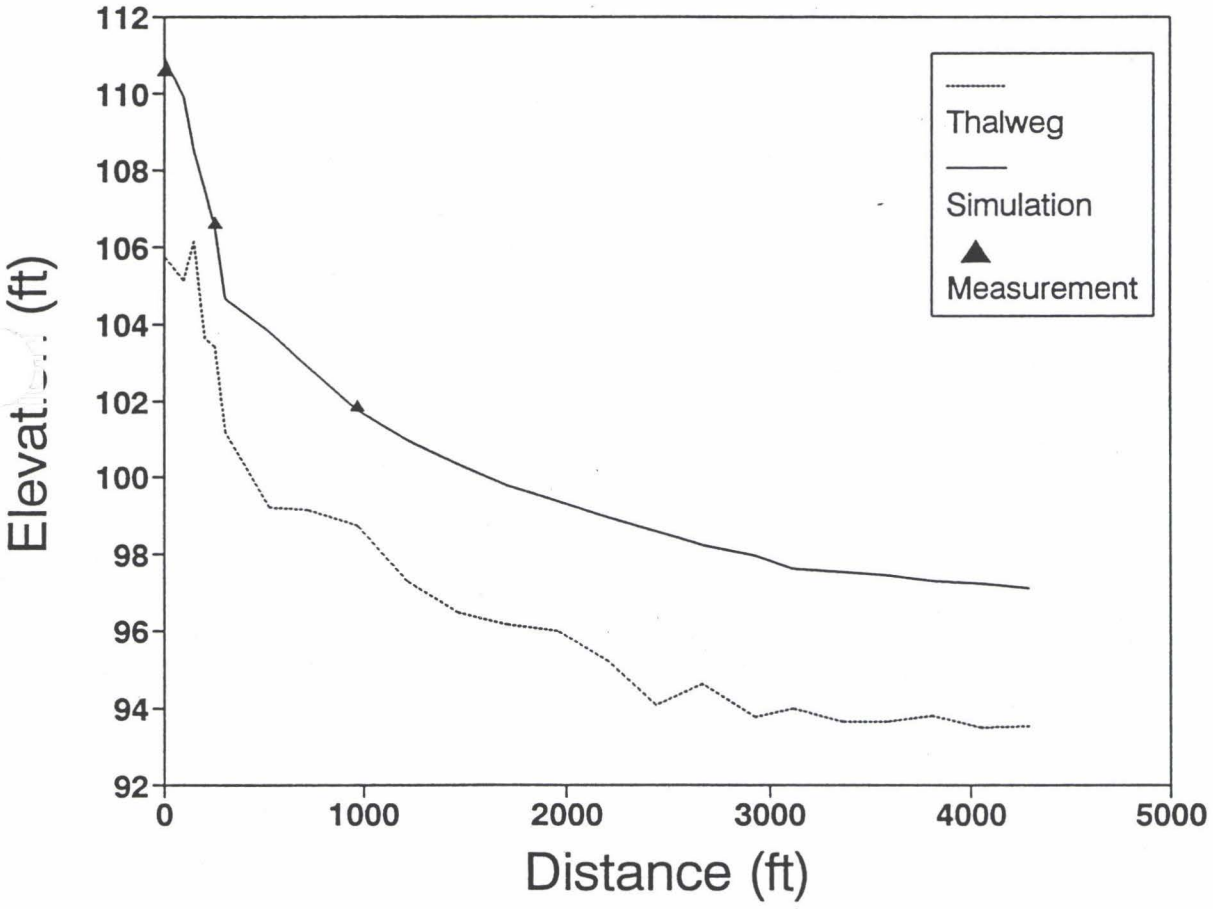
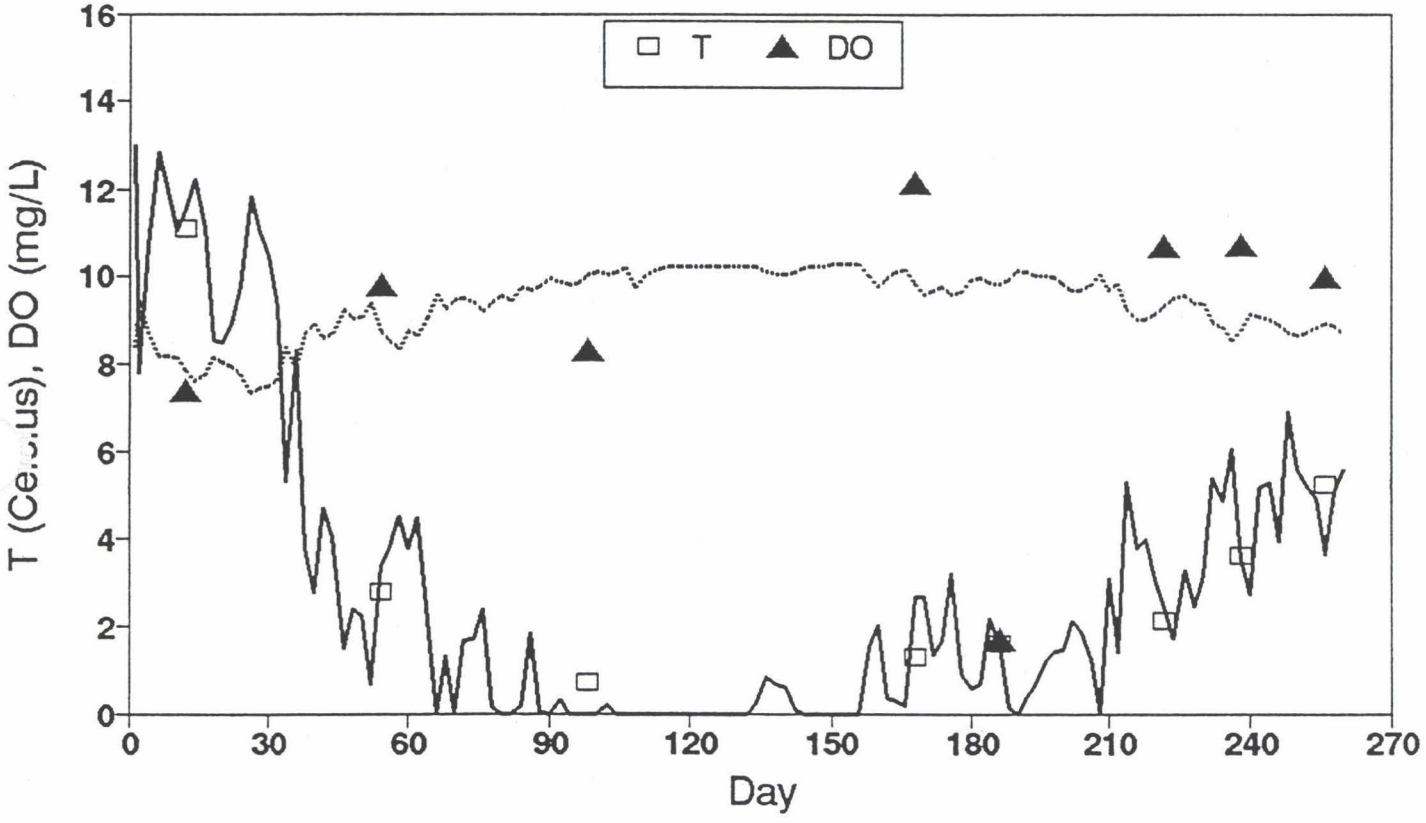
Elevation (ft)
0
1000
2000
3000
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

jd-163


Elevat... (ft)
112
110
108
106
104
102
100
98
96
94
92
0
1000
2000
3000
4000
5000
Distance (ft)
Thalweg
Simulation
Measurement

Dissolved Oxygen and Water Temperature Simulations

redd 4


T
DO
T (Celsius), DO (mg/L)
Day
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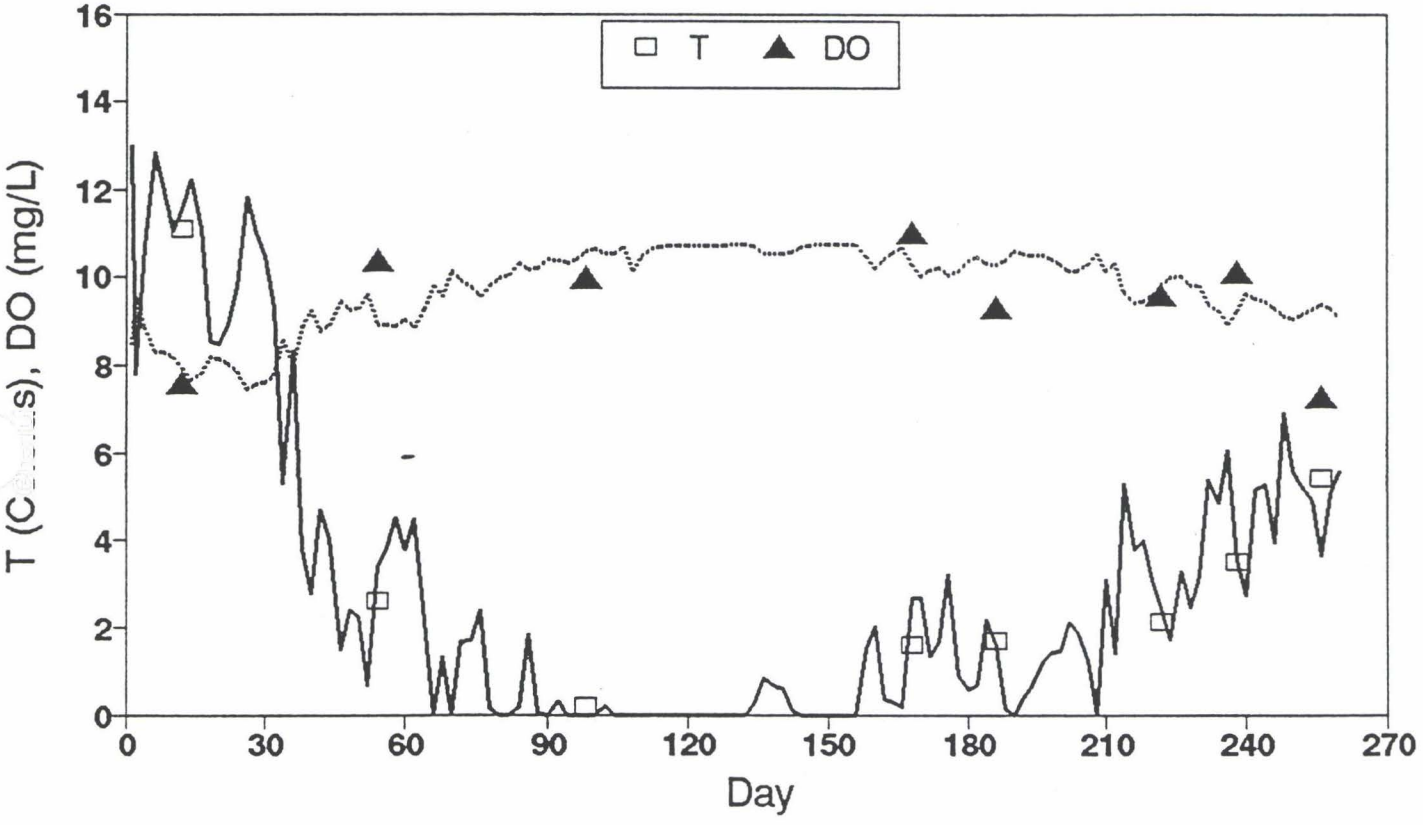
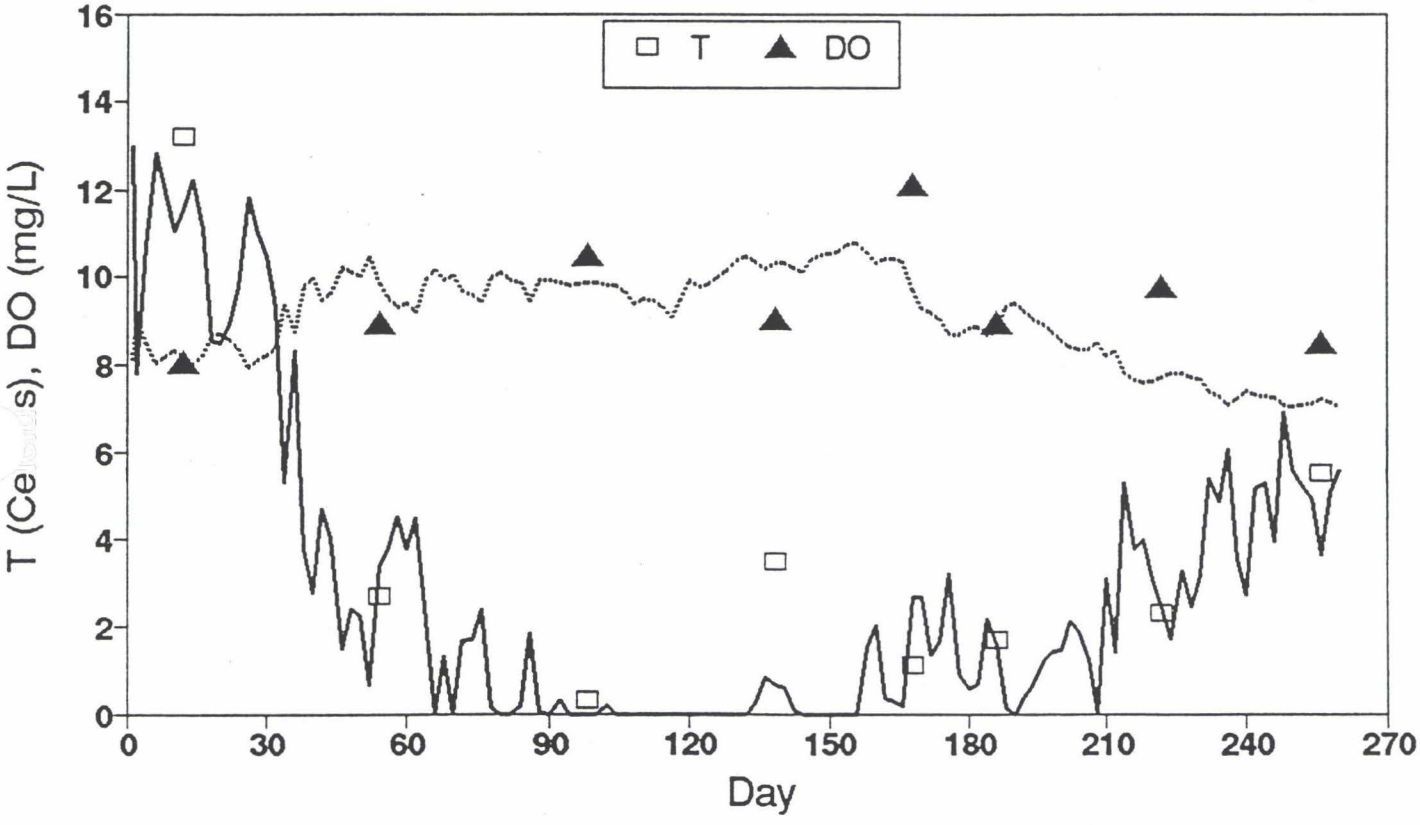
30
60
90
120
150
180
210
240
270
2
4
6
8
10
12
14
16

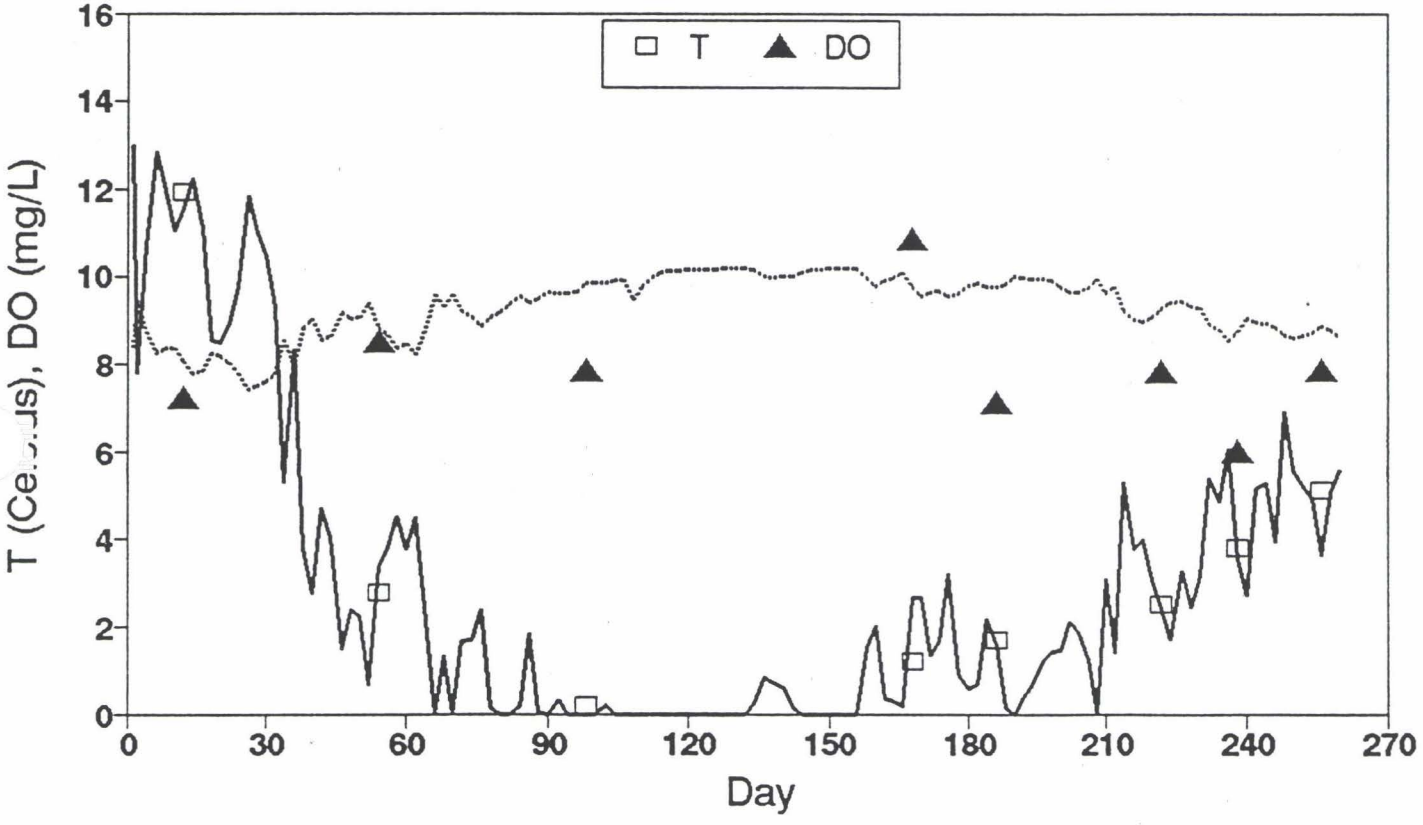
redd 5


T
DO
T (C), DO (mg/L)
Day
0
2
4
6
8
10
12
14
16
0
30
60
90
120
150
180
210
240
270

redd 6


T
DO
T (Celsius), DO (mg/L)
Day
0
2
4
6
8
10
12
14
16
0
30
60
90
120
150
180
210
240
270

redd 7


T
DO
T (Celsius), DO (mg/L)
Day
0
2
4
6
8
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12
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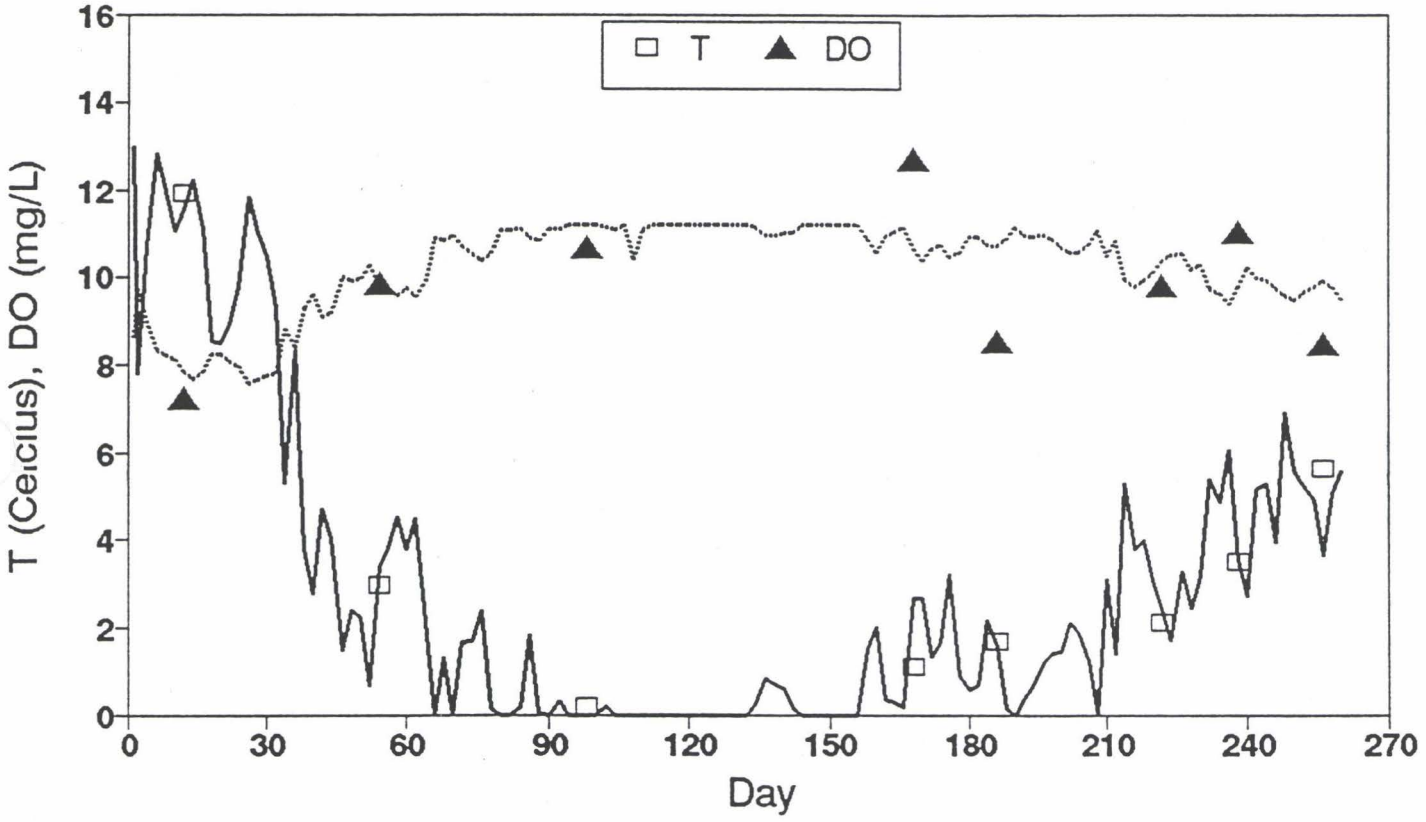
16
0
30
60
90
120
150
180
210
240
270

redd 8


T
DO
T (Celcius), DO (mg/L)
Day
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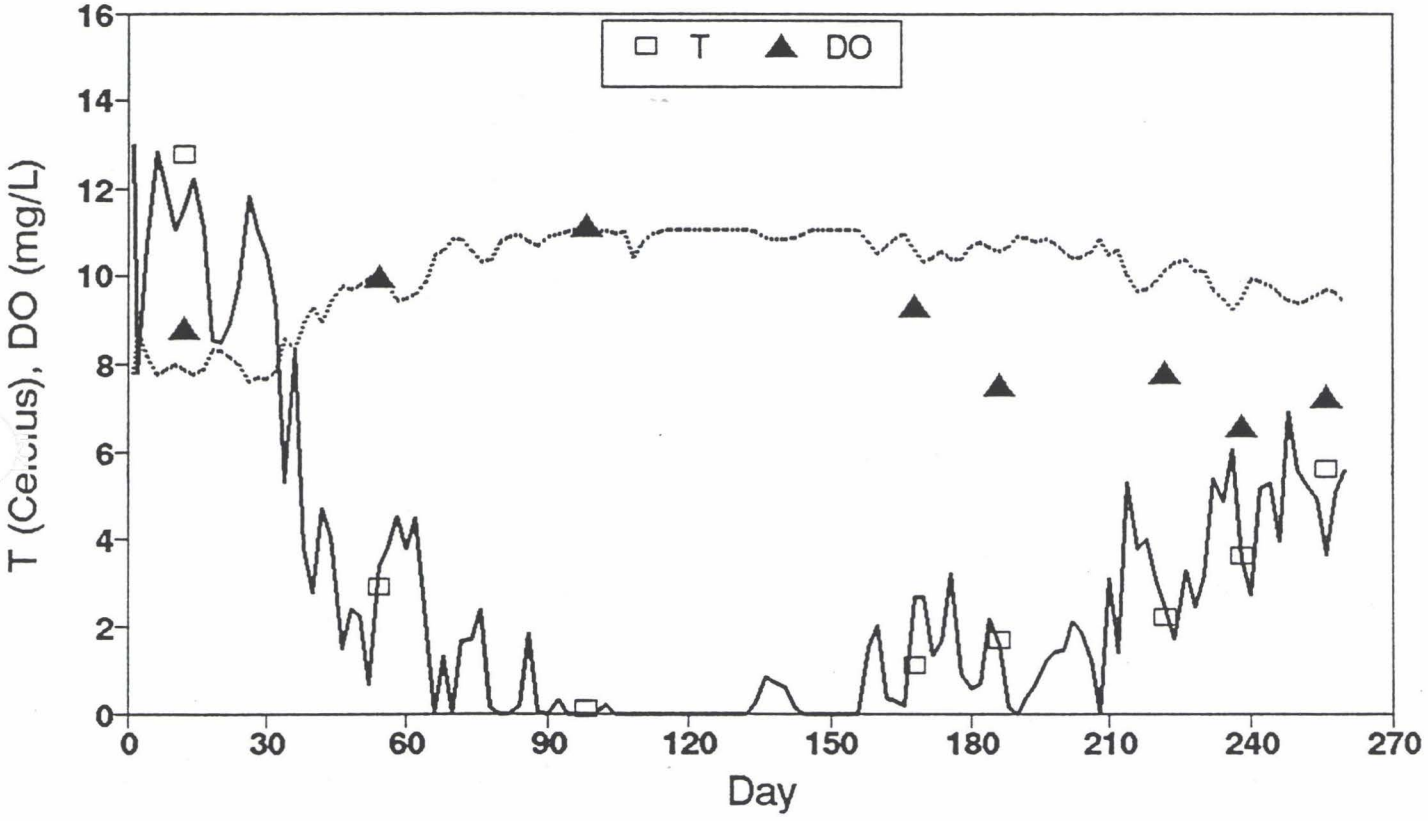
210
240
270

redd 9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DO
T (Celsius), DO (mg/L)
Day
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12
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16
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120
150
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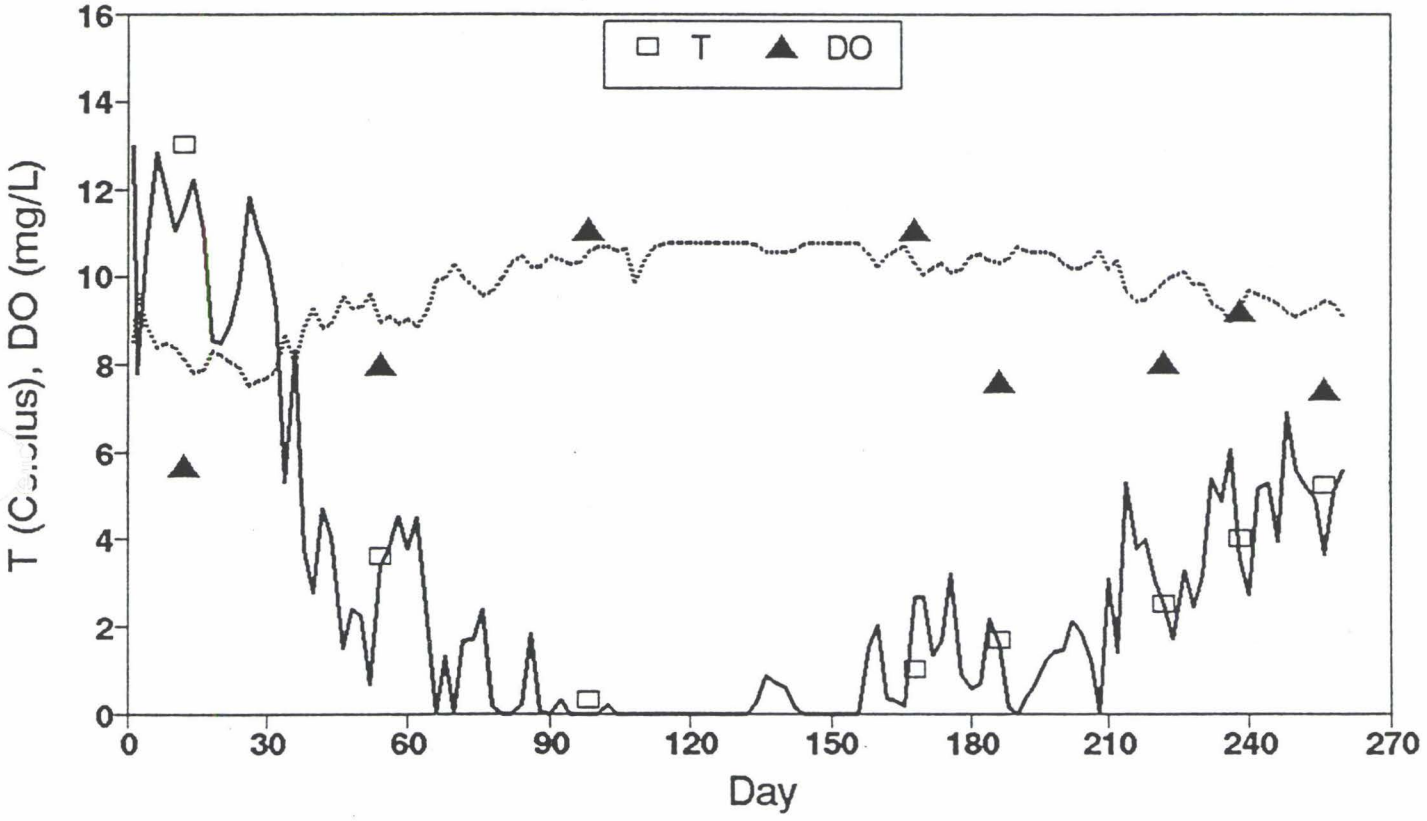
210
240
270

redd 10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DO
T (Celsius), DO (mg/L)
Day
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4
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